IMPACT OF EFFLUENT FROM FERTILIZER FACTORIES ON THE LAKHYA RIVER WATER QUALITY

Submitted by

Mohammad Hafizul Islam

(Roll No. 040404519F)

বাংলাদেশ প্রকৌশল বিশ্ববিদ্যালয়
নং 105955
তাং 25.10.08
লাইব্রেরী, ঢাকা

#105955#

In partial fulfillment of the requirement for the degree of
Master of Science in Civil Engineering (Environmental)

Department of Civil Engineering
Bangladesh University of Engineering and Technology
Dhaka, Bangladesh

August, 2008

Certificate of Research

This is to certify that this thesis work has been done by me and neither this thesis nor any part thereof has been submitted elsewhere for the award of any degree or diploma.

August, 2008

Mohammad Hafizul Islam

The thesis titled **"IMPACT OF EFFLUENT FROM FERTILIZER FACTORIES ON THE LAKHYA RIVER WATER QUALITY"** submitted by MOHAMMAD HAFIZUL ISLAM, Roll No 040404519F, Session: April 2004 has been accepted as satisfactory in partial fulfillment of the requirement for the degree of Master of Science in Civil Engineering (Environmental) on 10th August, 2008

BOARD OF EXAMINERS

Dr. Md. Mafizur Rahman
Professor
Department of Civil Engineering
BUET, Dhaka-1000, Bangladesh

Chairman
(Supervisor)

Dr. Muhammad Zakaria
Professor and Head
Department of Civil Engineering
BUET, Dhaka-1000, Bangladesh

Member
(Ex-officio)

Dr. M. Habibur Rahman
Professor
Department of Civil Engineering
BUET, Dhaka-1000, Bangladesh

Member

Dr. Md. Jahir Bin Alam
Associate Professor and Head
Department of Civil and Environmental Engineering
Shahjalal University of Science and Technology
Sylher-3114, Bangladesh

Member
(External)

DEDICATED

To

My beloved parents, Mushfik

ACKNOWLEDGEMENT

The author wishes to express his deepest gratitude and indebtedness to his supervisor Dr. Md. Mafizur Rahman, Professor, Department of Civil Engineering, BUET for his persistent guidance and encouragement in all stages of this research work .The author consider it a great opportunity to have a share of his knowledge and expertise in the field of industrial effluent and water quality.

The author is greatful to Dr.Muhammad Zakaria, Professor and Head, Department of Civil Engineering, BUET, Dr. M. Habibur Rahman, Professor, Department of Civil Engineering, BUET, and Dr. Md. Jahir Bin Alam, Associate Professor and Head, Department of Civil and Environmental Engineering, Shahjalal University of Science and Technology, Sylhet for their valuable suggestions for the improvement of the organization and contents of this thesis.

The author is indebted to Institute of Water Modelling (IWM), which organization incredibly helped providing Lakhya River flow data, library facilities and computer facilities to carry out the research work. Sincerest gratitude is expressed to Mr. Abu Saleh Khan, Executive Engineer, BWDB and Head, Flood Management Division, Institute of Water Modelling; Mr. Tarun Kanti Magumdar, Associate Specialist, Institute of Water Modelling. They have given their valuable suggestions to the author frequently to accomplish the research.

The author profoundly acknowledges the continuous support of his family, especially Yaameem, Protik, Juthi and Tithi during the course of study. Very special thanks to Essa-Ruhullah and Shamima easmin for their cordial assistance, understanding and loving concern at every stage of the thesis.

Finally, the author greatly acknowledges the continuous inspiration, constructive criticism and kind co-operation of his friend, Engineer Wasiqur Rahman, at every stages of the study. Without his cordial assistance, it would not be possible to complete this study in time.

Above all, the author prays to Almighty Allah for being in good health and condition, and for the successfully completion of the study.

Mohammad Hafizul Islam
August, 2008

ABSTRACT

Industrialization has become essential for economic growth and employment generation in Bangladesh. But the speeding up of the process of industrialization without adequate waste management facilities has become the cause of degradation of environment and quality of life. Indiscriminate disposal of polluting wastes beyond assimilation capacity of the water bodies has become the cause of deterioration of water quality and aquatic ecosystem. The Buriganga, the Dhaleswari, the Lakhya, and the Balu rivers have become highly contaminated around the industrial clusters. For instance, The Urea Fertilizer Factories (Polash and Ghorasal) produce around 1,400 tons urea per day. The industry has an effluent treatment plant with inadequate capacity. Most of the untreated effluent is being discharged into the Lakhya River through pump. A study was carried out in Polash and Ghorasal Urea Fertilizer Factories to assess the impact of effluent on the Lakhya River water quality. Comprehensive waste water sampling by grab sampling method and flow measurement by float velocity method were carried out for five weeks (one sample per week) at five sampling stations at Polash and Ghorasal Urea Fertilizer Factories during June-July, 2007. Water quality samplings by grab sampling method were also carried out for five weeks (one sample per week) at four stations in the Lakhya River system at the same time and River flows on the period of October-06 to September-07 were collected from Institute of Water Modelling. Effluents at both the places and the water sample from selected points in the river were analysed for pH, Temperature, DO, BOD_5, COD, NH_3-N, NH_4-N, TS, TSS, and TDS during June-July, 2007 at the Environmental Engineering workshop of Bangladesh University of Engineering and Technology, Bangladesh. The results showed that the effluents were alkaline while the level of DO, BOD_5, COD, NH_3-N, NH_4-N, TS, TSS, and TDS relatively high. The upstream water was near to neutral pH (average pH, 7.66±0.102) with high dissolved oxygen but low in the levels of the other parameters. The river water after the effluent discharge points was alkaline (average pH, 8.16±0.08) and the levels of other parameters were high due to heavy pollution load especially Ammonia discharged from fertilizer factories. The results suggested that the water in the river was polluted and not good for human consumption. It is therefore recommended that the disposal of improperly treated or untreated wastes should be stopped to save the river water from further deterioration. Although the values of some water quality parameters in some cases were lower than the allowable limits, the continued discharge of the effluents in the river may result in severe accumulation of the contaminants and unless the authorities implement the laws governing the disposal of wastes this may affect the lives of the people.

TABLE OF CONTENTS

			Page
ACKNOWLEDGEMENT			I
ABSTRACT			II
LIST OF FIGURES			VIII
LIST OF SCHEMATIC DIAGRAMS			XII
LIST OF TABLES			XIII
LIST OF PHOTOGRAPHS			XIV
LIST OF ABBREVIATIONS			XV
CHAPTER 1		**INTRODUCTION**	**1**
	1.1	Background	1
	1.2	Importance of the Study	2
	1.3	Objectives of the Study	2
	1.4	Organization of the Study	3
CHAPTER 2		**LITERATURE RIVIEW**	**4**
	2.1	Introduction	4
	2.1.1	Definition of water pollution	5
	2.1.2	Types of water pollution	5
	2.1.1.2	Surface water pollution	6
	2.1.3	Causes of water pollution	6
	2.1.4	Effluent	7
	2.1.4.1	Industrial Effluent	7
	2.2	Fertilizer factories in Bangladesh	8
	2.2.1	Manufacturing process involved in Polash and Ghorasal urea fertilizer factories	10
	2.2.2	Principle on urea production using carbamate solution total recycle process	10
	2.2.3	Pollutants from Polash and Ghorasal urea fertilizer factories	11

2.3		Why does pollution matter	12
	2.3.1	How do we know when water is polluted	12
2.4		Physical and Chemical properties	12
	2.4.1	pH	13
	2.4.2	Temperature	14
	2.4.3	Dissolved Oxygen (DO)	15
	2.4.4	Bio-Chemical Oxygen Demand (BOD)	16
	2.4.5	Chemical Oxygen Demand (COD)	18
	2.4.6	Total Solids	18
	2.4.7	Total Suspended Solids (TSS)	18
	2.4.8	Total Dissolved Solids (TDS)	19
	2.4.9	Ammonia	20
2.5		Biological parameters	21
	2.5.1	Total coliform and fecal coliform	21
	2.5.2	Algae	23
2.6		Environmental Quality Standards	23
2.7		Summary of previous works	28
CHAPTER 3		**SAMPLING AND ANALYSIS**	**31**
3.1		Introduction	31
3.2		Ghorasal and Polash urea fertilizer factories	31
3.3		Sample and Sampling	32
	3.3.1	Field trip preparations	32
	3.3.2	Selection of sampling site	32
	3.3.3	Water and waste water sampling	39
	3.3.4	Discharge measurements	39
3.4		Analysis of samples	39
3.5		Pollution load calculation	40
3.6		Standard Deviation calculation	40
CHAPTER 4		**CHARACTERIZATION OF EFFLUENT**	**41**
4.1		Introduction	41
4.2		Wastewater quality analysis	42
	4.2.1	Bio-chemical Oxygen Demand (BOD)	42
	4.2.2	Chemical Oxygen Demand (COD)	43
	4.2.3	Dissolved Oxygen (DO)	44
	4.2.4	pH	45

	4.2.5	Temperature	45
	4.2.6	Total Ammonia	46
	4.2.7	Ammonia as Nitrogen (NH_3-N)	47
	4.2.8	Ammonium as Nitrogen (NH_4-N)	48
	4.2.9	Total Solids (TS)	49
	4.2.10	Total Suspended Solids (TSS)	50
	4.2.11	Total Dissolved Solids (TDS)	50
CHAPTER 5		**ESTIMATION OF WATER POLLUTION LOAD**	**52**
5.1		Introduction	52
5.2		Estimation of effluent flow rate discharged from fertilizer factories	52
5.3		Estimation of water pollution load discharged from different sampling points of fertilizer factories	53
	5.3.1	Sampling point-4	53
	5.3.2	Sampling point-5	55
	5.3.3	Sampling point-7	56
5.4		Estimation of total water pollution load discharged from fertilizer factories	57
CHAPTER 6		**IMPACT OF EFFLUENT ON THE LAKHYA RIVER WATER QUALITY**	**59**
6.1		Introduction	59
6.2		Analysis of flow rate in the different points along the Lakhya River	59
	6.2.1	Sampling point-1	59
	6.2.2	Sampling point-6	60
	6.2.3	Sampling point-8	60
	6.2.4	Sampling point-9	60
6.3		Analysis of water quality along Lakhya River to assess impact of fertilizer factories effluent	61
	6.3.1	Bio-chemical Oxygen Demand (BOD)	61
	6.3.2	Chemical Oxygen Demand (COD)	62
	6.3.3	Dissolved Oxygen (DO)	62
	6.3.4	pH	63
	6.3.5	Temperature	64
	6.3.6	Total Ammonia	64

	6.3.7	Ammonia as Nitrogen (NH_3-N)	65
	6.3.8	Ammonium as Nitrogen (NH_4-N)	66
	6.3.9	Total Solids (TS)	67
	6.3.10	Total Suspended Solids (TSS)	68
	6.3.11	Total Dissolved Solids (TDS)	68
6.4		Analysis of pollution load along Lakhya River to assess impact of fertilizer factories effluent	69
	6.4.1	Bio-chemical Oxygen Demand (BOD)	69
	6.4.2	Chemical Oxygen Demand (COD)	70
	6.4.3	Total Ammonia	70
	6.4.4	Ammonia as Nitrogen (NH_3-N)	71
	6.4.5	Ammonium as Nitrogen (NH_4-N)	72
	6.4.6	Total Solids (TS)	73
	6.4.7	Total Suspended Solids (TSS)	74
	6.4.8	Total Dissolved Solids (TDS)	75

CHAPTER	**7**	**SURFACE WATER QUALITY MODELLING**	**79**
7.1		Surface water quality modelling for Lakhya River	79
7.2		Effects on river water quality	80
	7.2.1	Bio-chemical Oxygen Demand (BOD)	80
	7.2.2	Chemical Oxygen Demand (COD)	80
	7.2.3	Total Ammonia	81
7.3		Relationship between River flow and concentration of Total Ammonia	82
7.4		Relationship between River flow and concentration of Ammonia	83
7.5		Relationship between River flow and concentration of Ammonium	84
7.6		Relationship between River flow and concentration of Biochemical Oxygen Demand (BOD_5)	85
7.7		Relationship between River flow and concentration of Chemical Oxygen Demand (COD)	86
7.8		Relationship between River flow and concentration of Total Solids (TS)	87
7.9		Relationship between River flow and concentration of Total Dissolved Solids (TDS)	88
7.10		Comparision of correlation co-efficient of different water quality parameters	89
7.11		Comparision between up stream and down stream water quality parameters	89
	7.11.1	Total Ammonia	89

	7.11.2	Ammonia as Nitrogen (NH_3-N)	90
	7.11.3	Ammonium as Nitrogen (NH_4-N)	91
	7.11.4	Bio-chemical Oxygen Demand (BOD)	92
	7.11.5	Chemical Oxygen Demand (COD)	93
	7.11.6	Total Solids (TS)	94
	7.11.7	Total Dissolved Solids (TDS)	95
7.12		Relationship between Temperature and Dissolved Oxygen along the Lakhya River	96
7.13		Percent saturation Dissolved Oxygen along the Lakhya River	97
7.14		Development of industrial policy from impact of effluent	98
	7.14.1	Ammonia	98
	7.14.2	Ammonium	98
	7.14.3	Bio-chemical Oxygen Demand (BOD)	99
	7.14.4	Chemical Oxygen Demand (COD)	100
	7.14.5	Total Solids (TS)	100
	7.14.6	Total Dissolved Solids (TDS)	101

CHAPTER	**8**	**CONCLUSION AND RECOMMENDATIONS**	**102**
8.1		Conclusion	102
8.2		Recommendations	108
	8.2.1	Introduction	108
	8.2.2	Recommending Intervensions to minimize impact	108
	8.2.3	Limitations of the study	110
	8.2.4	Recommendations for further study	111
REFERENCES			112
APPENDIX			A-1

LIST OF FIGURES

		Page
Figure 3.1	Sampling point locations	35
Figure 4.1	Variation of BOD5 in mg/l at different sampling points of fertilizer factories	43
Figure 4.2	Variation of COD in mg/l at different sampling points of fertilizer factories	44
Figure 4.3	Variation of DO in mg/l at different sampling points of fertilizer factories	44
Figure 4.4	Variation of pH at different sampling points of fertilizer factories	45
Figure 4.5	Variation of Temperature in oC at different sampling points of fertilizer factories	46
Figure 4.6	Variation of Total Ammonia at different sampling points of fertilizer factories	47
Figure 4.7	Variation of NH3-N at different sampling points of fertilizer factories	48
Figure 4.8	Variation of NH4-N at different sampling points of fertilizer factories	49
Figure 4.9	Variation of Total Solids at different sampling points of fertilizer factories	49
Figure 4.10	Variation of TSS at different sampling points of fertilizer factories	50
Figure 4.11	Variation of TS at different sampling points of fertilizer factories	51
Figure 5.1	Variation of effluent flow rate at different sampling point of fertilizer factories	52
Figure 5.2	Variation of BOD5 and COD in kg/day discharged load of from sampling point-4 into the Lakhya River	53
Figure 5.3	Variation of Total Ammonia, Ammonia and Ammonium in kg/day discharged from sampling point-4 into the Lakhya River	54
Figure 5.4	Variation of total solids, total suspended solids and total dissolved solids in kg/day discharged from sampling point-4 into the Lakhya River	54
Figure 5.5	Variation of BOD, COD, Total Ammonia, TS, TSS, and TDS in kg/day discharged from residential area of fertilizer factories into the sampling point-4	54
Figure 5.6	Variation of BOD5 and COD in kg/day discharged load of from sampling point-5 into the Lakhya River	55
Figure 5.7	Variation of Total Ammonia, Ammonia and Ammonium in kg/day discharged from sampling point-5 into the Lakhya River	55
Figure 5.8	Variation of total solids, total suspended solids and total dissolved solids in kg/day discharged from sampling point-5 into the Lakhya River	56
Figure 5.9	Variation of BOD5 and COD in kg/day discharged load of from sampling point-5 into the Lakhya River	56
Figure 5.10	Variation of Total Ammonia, Ammonia and Ammonium in kg/day discharged from sampling point-5 into the Lakhya River	57

Figure 5.11	Variation of total solids, total suspended solids and total dissolved solids in kg/day discharged from sampling point-5 into the Lakhya River	57
Figure 5.12	Variation of BOD5 and COD in kg/day discharged from sampling point-5 into the Lakhya River	58
Figure 5.13	Variation of Total Ammonia, Ammonia and Ammonium in kg/day discharged from sampling point-5 into the Lakhya River	58
Figure 5.14	Variation of total solids, total suspended solids and total dissolved solids in kg/day discharged from sampling point-5 into the Lakhya River	58
Figure 6.1	Variation of flow rate at sampling point-1 along the Lakhya River	59
Figure 6.2	Variation of flow rate at the sampling point-6 along the Lakhya River	60
Figure 6.3	Variation of flow rate at the sampling point-8 along the Lakhya River	60
Figure 6.4	Variation of flow rate at the sampling point-9 along the Lakhya River	61
Figure 6.5	Variation of BOD5 in mg/l along the Lakhya River	61
Figure 6.6	Variation of COD in mg/l along the Lakhya River	62
Figure 6.7	Variation of DO in mg/l along the Lakhya River	63
Figure 6.8	Variation of pH along the Lakhya River	63
Figure 6.9	Variation of Temperature along the Lakhya River	64
Figure 6.10	Variation of Ammonia in mg/l along the Lakhya River	65
Figure 6.11	Variation of NH3-N in mg/l along the Lakhya River	66
Figure 6.12	Variation of NH4-N in mg/l along the Lakhya River	67
Figure 6.13	Variations of Total Solids in mg/l along the Lakhya River	67
Figure 6.14	Variations of Total Suspended Solids in mg/l along the Lakhya River	68
Figure 6.15	Variation of Total Dissolved Solids in mg/l along the Lakhya River	69
Figure 6.16	Variation of BOD5 in kg/day along the Lakhya River	69
Figure 6.17	Variation of COD in kg/day along the Lakhya River	70
Figure 6.18	Variation of Total Ammonia in kg/day along the Lakhya River	71
Figure 6.19	Variation of Ammonia as Nitrogen (NH3-N) in kg/day along the Lakhya River	72
Figure 6.20	Variation of Ammonium as Nitrogen (NH4-N) in kg/day along the Lakhya River	73
Figure 6.21	Variation of Total Solids in kg/day along the Lakhya River	74
Figure 6.22	Variation of Total Suspended Solids in kg/day along the Lakhya River	75
Figure 6.23	Variation of Total Dissolved Solids in kg/day along the Lakhya River	75
Figure 7.1	Decay constant for BOD5 with distance	80
Figure 7.2	Decay constant for COD with distance	81
Figure 7.3	Decay constant for NH3-N with distance	81

Figure 7.4	Relationship between River flow and Total Ammonia concentration at sampling point-1	82
Figure 7.5	Relationship between River flow and Total Ammonia concentration at sampling point-9	82
Figure 7.6	Relationship between River flow and Ammonia concentration at sampling point-1	83
Figure 7.7	Relationship between River flow and Ammonia concentration at sampling point-9	83
Figure 7.8	Relationship between River flow and Ammonium concentration at sampling point-1	84
Figure 7.9	Relationship between River flow and Ammonium concentration at sampling point-9	84
Figure 7.10	Relationship between River flow and BOD5 concentration at sampling point-1	85
Figure 7.11	Relationship between River flow and BOD5 concentration at sampling point-9	85
Figure 7.12	Relationship between River flow and COD concentration at sampling point-1	86
Figure 7.13	Relationship between River flow and COD concentration at sampling point-9	86
Figure 7.14	Relationship between River flow and TS concentration at sampling point-1	87
Figure 7.15	Relationship between River flow and TS concentration at sampling point-9	87
Figure 7.16	Relationship between River flow and TDS concentration at sampling point-1	88
Figure 7.17	Relationship between River flow and TDS concentration at sampling point-9	88
Figure 7.18	Comparision of Total Ammonia concentration (simulated) between up stream and down stream	89
Figure 7.19	Comparision of Total Ammonia concentration (observed) between up stream and down stream	90
Figure 7.20	Comparision of Ammonia concentration (simulated) between up stream and down stream	90
Figure 7.21	Comparision of Ammonia concentration (observed) between up stream and down stream	91
Figure 7.22	Comparision of Ammonium concentration (simulated) between up stream and down stream	91
Figure 7.23	Comparision of Ammonium concentration (observed) between up stream and down stream	92
Figure 7.24	Comparision of BOD5 concentration (simulated) between up stream and down stream	92
Figure 7.25	Comparision of BOD5 concentrations (observed) between up stream and down stream	93

Figure 7.26	Comparision of COD concentration (simulated) between up stream and down stream	93
Figure 7.27	Comparision of COD concentrations (observed) between up stream and down stream	94
Figure 7.28	Comparision of TS concentrations (simulated) between up stream and down stream	94
Figure 7.29	Comparision of TS concentrations (observed) between up stream and down stream	95
Figure 7.30	Comparision of TDS concentration (simulated) between up stream and down stream	95
Figure 7.31	Comparision of TDS concentration (observed) between up stream and down stream	96
Figure 7.32	Relationship between Temperature and Dissolved Oxygen along the Lakhya River	96
Figure 7.33	Variation of percent saturation of Dissolved Oxygen along the Lakhya River	97
Figure 7.34	The load of Ammonia as percent of upstream load discharged from fertilizer factories into the Lakhya River	98
Figure 7.35	The load of Ammonia as percent of upstream load discharged from fertilizer factories into the Lakhya River	99
Figure 7.36	The load of BOD5 as percent of upstream load discharged from fertilizer factories into the Lakhya River	99
Figure 7.37	The load of COD as percent of upstream load discharged from fertilizer factories into the Lakhya River	100
Figure 7.38	The load of Total solids as percent of upstream load discharged from fertilizer factories into the Lakhya River	101
Figure 7.39	The load of Total Dissolved Solids as percent of upstream load discharged from fertilizer factories into the Lakhya River	101

LIST OF SCHEMATIC DIAGRAMS

		Page
Diagram 6.1	Different sources of BOD_5 along the Lakhya River	76
Diagram 6.2	Different sources of COD along the Lakhya River	76
Diagram 6.3	Different sources of Ammonia along the Lakhya River	77
Diagram 6.4	Different sources of Total Solids along the Lakhya River	77
Diagram 6.5	Different sources of Total Suspended Solids along the Lakhya River	78
Diagram 6.6	Different sources of Total Dissolved Solids along the Lakhya River	78

LIST OF TABLES

		Page
Table 2.1	Ranking of the industrial sectors (top five polluters)	9
Table 2.2	Emissions and Effluents of GUFFL and PUFFL	12
Table 2.3	EQS of some relevant water quality parameters, DOE 1991	24
Table 2.4	EQS of some relevant water quality parameters, DOE 1997	24
Table 2.5	Drinking water quality standards	24
Table 2.6	Maximum allowable concentrations of water quality variables for drinking	25
Table 2.7	Maximum allowable concentrations of water quality variables for Fisheries and other aquatic lives	26
Table 2.8	Industrial /Project Effluent Standards	27
Table 3.1	Detail of wastewater sampling and flow measurement locations	34
Table 3.2	Parameters tested for different wastewater sample	39
Table 3.3	Different methods of testing sample	40

LIST OF PHOTOGRAPHS

		Page
Photograph 3.1	Untreated effluent discharged into the Lagoon through this drain	36
Photograph 3.2	Untreated effluent discharged from Polash and Ghorasal urea fertilizer factories combine at this point	36
Photograph 3.3	Sampling point-2 (Lagoon)	36
Photograph 3.4	Sampling point-2 (Lagoon)	36
Photograph 3.5	Effluent discharged from Lagoon through these pump	36
Photograph 3.6	Effluent discharged from Lagoon through this drain	36
Photograph 3.7	Sampling point-3	37
Photograph 3.8	Effluent of sampling point-2 and 3 combine at this point	37
Photograph 3.9	House hold effluent discharged through this drain	37
Photograph 3.10	Household effluent, effluent of sampling point-2 and 3 combine at this point	37
Photograph 3.11	Sampling point-5 (Untreated effluent discharged into the Lakhya River through this drain in June-July, 2007)	37
Photograph 3.12	Sampling point-5 (Untreated effluent discharged into the Lakhya River through this drain in March-April, 2007)	37
Photograph 3.13	Sampling point-7	38
Photograph 3.14	Measurement of pH, DO, Temperature at the sampling site	38
Photograph 3.15	Water quality sampling at Lakhya River	38
Photograph 3.16	Removig of air bubble from water quality sampling at Lakhya River.	38

LIST OF ABBREVIATIONS

BOD	Bio-chemical Oxygen Demand
BUET	Bangladesh University of Engineering and Technology
COD	Chemical Oxygen Demand
DO	Dissolved Oxygen
DOE	Department of Environment
ECR	Environmental Conservation Rules
EQS	Environmental Quality Standards
EU	European Union
IWM	Institute of Water Modelling
MOEF	Ministry of Environment and Forest
NH_3-N	Ammonia as Nitrogen
NH_4-N	Ammonium as Nitrogen
SIDA	Swedish International Development Cooperation Agency
TS	Total Solids
TSS	Total Suspended Solids
TDS	Total Dissolved Solids
USEPA	United State Environmental Protection Agency
WARPO	Water Resources and Planning Organization
WB	World Bank
WHO	World Health Organization

বাংলাদেশ প্রকৌশল বিশ্ববিদ্যালয়
নং 105955
তা 25/10/08
লাইব্রেরী, ঢাকা

CHAPTER 1

INTRODUCTION

1.1 Background

Water is essential to all forms of life and makes up 50-97% of the weight of all plants and animals and about 70% of human body (Buchholz, 1998).Water is also a vital resource for agriculture, manufacturing, transportation and many other human activities. Despite its importance, water is the most poorly managed resource in the world (Fakayode, 2005). Ground and surface waters can be contaminated by several sources. In farming areas, the routine application of agricultural fertilizers is the major source (Altman and Parizek, 1995; Emongor et al., 2005). In urban areas, the careless disposal of industrial effluents and other wastes may contribute greatly to the poor quality of the water (Chindah et al., 2004; Emongor et al., 2005; Furtado et al., 1998 and Ugochukwu, 2004). A study on the impact of industrial effluent on water quality of a river carried out in Nigeria (Fakayode, 2005) showed that the chemical parameters studied were above the allowable limits and also tended to accumulate downstream. The increasing demand on water arising from fast growth of industries has put pressure on limited water resources. While most people in urban cities of the developing countries have access to piped water, several others still rely on borehole and river water for domestic use. Most of the rivers in the urban areas of the developing world are the end points of effluents discharged from the industries. Industrial effluents, if not treated and properly controlled can also pollute ground water (Olayinka, 2004; SARDC, 2005). Therefore, both bore holes and rivers generally have poor quality water in the affected areas. Since people use untreated waters from these sources, the result is continuous outbreaks of diseases such as cholera, diarrhoea, desyntry and others. Bangladesh is experiencing rapid industrial growth and this is making environmental conservation a difficult task (WB, 2007). Although the government has put in place policies for effective environmental conservation and natural resources management, lack of political will is impeding their implementation. This is also compounded by the fact that the industrial sector shifts the responsibility of pollution prevention to the government alone and this makes it difficult to prevent pollution. As a result, there is unsustainable and wasteful utilization of resources which give rise to dwindling wild life; more land degradation and increasing generation and indiscriminate disposal of commercial, industrial and domestic wastes.

In the capital city of Bangladesh, there are a number of big rivers that runs through an industrial site. The effluents from some industries are discharged into these rivers. People who live near the area use the water from the river for domestic purposes. Unfortunately, there is no information on the quality of the effluent discharged into this river and also on the quality of the water in the river for human use. Such information is important for the authorities to take proper action in preventing pollution of the environment for the good health of the population. The objective of this study was therefore to assess the extent of chemical pollution in receiving rivers as affected by industrial effluents discharged therein.

1.2 Importance of the Study

Industrialization has become essential for economic growth and employment generation in Bangladesh. But the speeding up of the process of industrialization without adequate waste management facilities has become the cause of degradation of environment and quality of life. Indiscriminate disposal of polluting wastes beyond assimilation capacity of the water bodies has become the cause of deterioration of water quality and aquatic ecosystem (WB-2007). The Buriganga, the Dhaleswari, the Lakhya, and the Balu rivers have become highly contaminated around the industrial clusters (IWM-2004 and SIDA-2006). For instance, The Urea Fertilizer Factories (Polash and Ghorasal) produce around 1,400 tons urea per day. The industry has an effluent treatment plant with inadequate capacity. Most of the untreated effluent is being discharged into the Lakhya River through pump. In this connection, Interventions are required to minimize impact (WB-2007).

1.3 Objectives of the Study

Objectives of the study are mentioned as follows:

- Characterization of effluent from fertilizer factories
- Estimation of water pollution load discharged from fertilizer factories
- Analysis of water quality along the Lakhya River to assess impact of fertilizer factories effluent
- Recommending interventions to minimize impact

The study will help in formulation of policy for minimizing the surface water pollution, contributed by the fertilizer factories.

1.4 Organization of the Study

The present study is organized as follows. Chapter 1 provides an introduction with background, importance, objectives and organization of the study, Chapter 2 describes Literature Review on water quality, effluent from fertilizer factories and their impact on River water quality, Summary of previous works, Chapter 3 provides site selection, point of data collection, methodology for data collection, analysis of sample, Chapter 4 describes the characteristics of effluent from fertilizer factories, Chapter 5 describes the analysis of effluent flow rate and estimation of water pollution load discharged from fertilizer factories, Chapter 6 describes the analysis of water quality and water pollution load along the Lakhya River to assess impact of fertilizer factories effluent, Chapter 7 describes decay constant of different water quality parameters, Relationship between River flow and different water quality parameters, Comparision between up stream and down stream water quality parameters, Development of industrial policy from impact of effluent; Chapter 8 provides the conclusion on the present study, recommending interventions to minimize impact and recommendations for the future research work.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

Water is the most vital element among the natural resources, and is crucial for the survival of all living organisms. The environment, economic growth and development of Bangladesh are all highly influenced by water - its regional and seasonal availability, and the quality of surface and groundwater. Spatial and seasonal availability of surface and groundwater is highly responsible to the monsoon climate and physiography of the country. Availability also depends on upstream withdrawal for consumptive and nonconsumptive uses. In terms of quality, the surface water of the country is unprotected from untreated industrial effluents and municipal wastewater, runoff pollution from chemical fertilizers and pesticides, and oil and lube spillage in the coastal area from the operation of sea and river ports. Water quality also depends on effluent types and discharge quantity from different type of industries, types of agrochemicals used in agriculture, and seasonal water flow and dilution capability by the river system.

The increasing urbanization and industrialization of Bangladesh have negative implications for water quality. The pollution from industrial and urban waste effluents and from agrochemicals in some water bodies and rivers has reached alarming levels. The long-term effects of this water contamination by organic and inorganic substances, many of them toxic, are incalculable. The marine and aquatic ecosystems are affected, and the chemicals that enter the food chain have public health implications. Water quality in the coastal area of Bangladesh is degraded by the intrusion of saline water that has occurred due to lean flow in the dry season.

In particular, water quality around Dhaka is so poor that water from the surrounding rivers can no longer be considered as a source of water supply for human consumption. The largest use of water is made for irrigation. Besides agriculture, some other uses are for domestic and municipal water supply, industry, fishery, forestry and navigation. In addition, water is of fundamental importance for ecology and the wider environment. Water stress occurs when the demand for water exceeds the amount available during a certain period or when poor quality restricts its use.

2.1.1 Definition of water pollution

Poorer water quality means water pollution. Water pollution can be defined in many ways. Usually, it means one or more substances have built up in water to such an extent that they cause problems for animals or people.

Water pollution almost always means that some damage has been done to an ocean, river, lake, or other water source. A 1971 United Nations report defined ocean pollution as: *"The introduction by man, directly or indirectly, of substances or energy into the marine environment (including estuaries) resulting in such deleterious effects as harm to living resources, hazards to human health, hinderance to marine activities, including fishing, impairment of quality for use of sea water and reduction of amenities."* Fortunately, Earth is forgiving and damage from water pollution is often reversible.

2.1.2 Types of water pollution

Water resources like oceans, lakes, and rivers are called surface waters. The most obvious type of water pollution affects surface waters. A great deal of water is held in underground rock structures known as aquifers. Water stored underground in aquifers is known as groundwater.

Surface water and groundwater are the two types of water resources that pollution affects. There are also two different ways in which pollution can occur. If pollution comes from a single location, such as a discharge pipe attached to a factory, it is known as point-source pollution. Other examples of point source pollution include an oil spill from a tanker, a discharge from a smoke stack (factory chimney), or someone pouring oil from their car down a drain. A great deal of water pollution happens not from one single source but from many different scattered sources. This is called nonpoint-source pollution.

When point-source pollution enters the environment, the place most affected is usually the area immediately around the source. This is less likely to happen with nonpoint source pollution which enters the environment from many different places at once. Sometimes pollution that enters the environment in one place has an effect hundreds or even thousands of miles away. This is known as transboundary pollution. One example is the way radioactive waste travels through the oceans from nuclear reprocessing plants in England and France to nearby countries such as Ireland and Norway.

2.1.2.1 Surface Water Pollution

Surface water quality are gradually emerging due to the dispersed locations of polluting industries and the adverse effect on surrounding land and aquatic ecosystems, as well as subsequent impacts on the livelihood system of the local community. The extreme examples of this type of effect are near Dhaka at Konabari and Savar, where industrial effluents are discharged into nearby land and water bodies without any treatment. Among the polluted areas, the worst problems are in the River Buriganga situated to the south of Dhaka, where the most significant source of pollution appears to be from tanneries in the Hazaribagh area. In the dry season, the dissolved oxygen level becomes very low or non-existent and the river becomes toxic (WARPO, 1999). The second most polluted river is the Shitalakhya, flowing from the east of Dhaka. The major polluters of the river are Ghorashal Urea Fertilizer Factory and an oil terminal situated on the bank of the river. Industrial units at Narayanganj and Demra are also sources of the pollution. Water of the river Balu is badly contaminated by urban and industrial wastes from Tongi and the effluent flowing out through the Begubari Khal, most of which emanates from the Tejgaon industrial area in Dhaka. In the rivers Balu and Turag, water quality in the dry season becomes worse, with DO concentrations becoming almost zero (Saad, 2000).

2.1.3 Causes of Water Pollution

The major causes of degradation of inland water quality are related to land based activities, when adequate regulatory measures are not incorporated and the stakeholders do not show proper concern. The underlying driving forces for this are poverty, an unhealthy national economy, lack of institutional strength, and lack of awareness and education. Pollutants that enter the marine and coastal environment originate on land in the form of runoff from municipal, industrial and agricultural wastes, and from commercial seafaring activities. Most water pollution doesn't begin in the water itself. Take the oceans: around 80 percent of ocean pollution enters our seas from the land. Virtually any human activity can have an effect on the quality of our water environment. When farmers fertilise the fields, the chemicals they use are gradually washed by rain into the groundwater or surface waters nearby. Sometimes the causes of water pollution are quite surprising. Chemicals released by smokestacks (chimneys) can enter the atmosphere and then fall back to earth as rain, entering seas, rivers, and lakes and causing water pollution. Water pollution has many different causes and this is one of the reasons why it is such a difficult problem to solve.

2.1.4 Effluent

Effluent is liquid waste product (whether treated or untreated) discharged from an industrial process or human activity that is discharged into the environment.

Effluent is a waste product, which could be in any of the three states of matter, discharged from boundary of manufacturers to the environment (Bridgewater and Mumfod, 1979). They are wastes resulting from processes employed in industrial establishments to the environment; they could be reused after recovery. Water, which has been described by many as the most essential commodity required for man's survival has received enormous environmental abuse. Process industries and sewage systems are particularly guilty of pollution of water systems (Asubiojo et al., 1993).

2.1.4.1 Industrial effluent

In Bangladesh, industrial units are mostly located along the banks of the rivers. There are obvious reasons for this such as provision of transportation for incoming raw materials and outgoing finished products. Unfortunately as a consequence, industrial units drain effluents directly into the rivers without any consideration of the environmental degradation. The most problematic industries for the water sector are textiles, tanneries, pulp and paper mills, fertilizer, industrial chemical production and refineries. A complex mixture of hazardous chemicals, both organic and inorganic, is discharged into the water bodies from all these industries usually without treatment. The highest numbers of industrial establishments in the country are located in the North Central (NC) region, which comprises about 49 per cent of the total sector. About 33 per cent of the industries in the NC region are textiles, apparels and tanneries, of which Dhaka district accounts for almost half and Narayanganj about 32 per cent. About 65 per cent of the total chemicals, plastics and petroleum industries are also located in the NC region, and concentrated in and around Dhaka, Narayanganj and Gazipur districts (WARPO, 2000). The organic pollutants are both biodegradable and non-biodegradable in nature. The biodegradable organic components degrade water quality during decomposition by depleting dissolved oxygen. The non-biodegradable organic components persist in the water system for a long time and pass into the food chain (Ahmed and Reazuddin, 2000). Inorganic pollutants are mostly metallic salts, and basic and acidic compounds. These inorganic components undergo different chemical and biochemical interactions in the river system, and deteriorate waterquality.

2.2 Fertilizer factories in Bangladesh

There are eight public fertilizer factories in Bangladesh falling under three categories and ting under the jurisdiction of Bangladesh Chemical Industries Corporation (BCIC):

Ammonia-urea production complexes

- Ghorashal Urea Fertilizer Factory at Ghorashal (GUFFL)
- Polash Urea Fertilizer Factory at Ghorashal (PUFL)
- Zia Fertilizer Factory at Ashuganj (ZFL)
- Chittagong Urea Fertilizer Factory at Chittagong (CUFL)
- Natural Gas Fertilizer Factory at Fenchuganj (NGFL)
- Jamuna Fertilizer Factory at Jamalpur (JFL)

Triple Super phosphate (TSP) production complex

- T.S.P Complex at Chittagong

Ammonia Sulphate production complex

- Ammonia Sulphate Complex

In addition, there is one private sector plant belonging to KAFCO (DOE, 1994). Limited data is available on the type of waste generated, and physical and chemical characteristics of effluent produced in both urea and phosphate plants. A study conducted by Islam et ai, 1994 shows that (Table 2.1) the rank of fertilizer factory as a pollutant in context of water; pollution is fifth in Bangladesh. The acidic and alkaline waste generated from fertilizer. Factories affect aquatic life. Ammonia present in the waste is toxic to fish. The amines have high oxygen and chlorine values. Rainwater runoff from storage areas carries dissolved and suspended solids, urea dust, and other materials such as, chromium and nickel. Phosphate from T.S.P. complex can accelerate the growth of algae and other aquatic weeds. Ammonia and urea dust may affect land areas around the fertilizer plants. Other substances found in the effluent of fertilizer factories that are toxic to aquatic life are urea, hydrogen sulfide, hydrogen cyanide, arsenic, methanol and fluorides. Sometimes fine carbon particle in the effluent reduces dissolved oxygen content of the receiving stream.

Table 2.1 Ranking of the industrial sectors (top five polluters)

Rank	Industrial sector	Emission (tons/year)	Percent contribution	Cumulative percent
	Air pollution			
1	Food industry	146356.06	38.7%	38.7%
2	Cement/Clay	62725.88	16.6%	55.3%
3	Pulp and paper	51963.92	13.7%	69.0%
4	Textile	39831.01	10.5%	79.5%
5	Tobacco	16992.22	4.5%	84.0%
	Water pollution			
1	Pulp and paper	91768.10	47.4%	47.4%
2	Pharmaceuticals	30866.72	15.9%	63.3%
3	Metal	27174.61	14.0%	77.3%
4	Food industry	23403.39	12.1%	89.4%
5	Fertilizers/pesticides	12715.00	6.6%	96.0%
	Toxic metals emission			
1	Metal	1071.92	28.3%	28.3%
2	Cement/Clay	688.90	18.2%	46.6%
3	Tanneries/leather	659.38	17.4%	64.0%
4	Fertilizers/pesticides	407.30	10.8%	74.8%
5	Textile	192.46	5.1%	79.8%
	Toxic chemicals emission			
1	Tanneries/leather	13630.55	20.6%	20.6%
2	Pulp and paper	10132.96	15.3%	35.9%
3	Pharmaceuticals	8362.393	12.6%	48.6%
4	Fertilizers/pesticides	8226.275	12.4%	61.0%
5	Industrial chemicals	5713.782	8.6%	69.6%

In addition to pollution, several occupational hazards have taken place in fertilizer factories due to lack of safety measures. Workers are subjected to noice pollution and various health risks from breathing urea dust gaseous ammonia.

2.2.1 Manufacturing Process Involved in Polash and Ghorasal Urea Fertilizer Factories

The People's Republic of Bangladesh is designed to produce 305 and 1100 tons of uncoated urea per steam day using carbamate solution total recycle process from Polash and Ghorasal urea fertilizer factories respectively. The process adopts two stages of decomposition, three stages of absorption, two stages of evaporation and partially heat recovery system. It is characterized by stable production, easy operation and high product quality. Urea production process is generally divided into the following sections

- Compression of CO_2
- Purification and transportation of ammonia
- Systhesis of urea
- Recycle System
    - *Primary recycling*
    - *Secondary recycle*
- Evaporating, prilling and storage
    - *Flashing*
    - *Evaporating*
    - *Prilling and Storing*
- Tail absorption
- Utilities
    - Steam System
        - *Expanded steam*
        - *Saturated steam system*
    - Steam condensate system
    - Cooling water system
    - Nitrogen system
    - Air system

2.2.2 Principle on Urea Production Using Carbamate Solution Total Recycle Process

I. Synthesis of urea

1. Synthesis reaction of urea

Synthesis reaction of urea is conducted in liquid phase in two successive steps. In the first

step, ammonia reacts with CO to from into ammonium carbamate.

$$2NH3 + C0_2 = NH_4COONH_2 + Q_1$$

This is an exothermal reaction at a rapid speed and it easily obtains its equilibrium under which the conversion rate of $C0_2$ to ammonium carbamate is considerably high. While in the second step, the ammonium carbamate is dehydrated to form into urea.

$$NH_4COONH_2 = NH_2CONH_2 + H_2O - Q_2$$

It is a slightly endothermic reaction at a comparatively low speed and requires a considerable length of time to obtain equilibrium. And even equilibrium is achieved, it is still impossible for all the carbamate to be dehydrated to form urea. Hence the conversion rate is much lower as compared with the first step. Thus the second step serves as the control reaction in the urea synthesis.

It should be pointed out that the reaction in which carbamate is dehydrated to from urea must be carried out in liquid phase, i.e. the carbamate must be under molten state, so the reaction temperature must be higher than that of melting point. Since decomposition of carbamate is favored by high temperature, a considerably high pressure should be maintained to ensure the stability of carbamate. Therefore the synthesis reaction of urea may be realized only under high pressure and high temperature conditions.

2. Effect of various factors on the conversion rate of systhesis reaction of urea

II. Separation and recovery of the unreacted feed materials

III. Formation of biuret

2.2.3 Pollutants from Polash and Ghorasal urea Fertilizer Factories

GUFFL and PUFFL has i) utility unit (water treatment unit, IG plant, Auxiliary boiler, cooling water and waste water treatment plant), ii) ammonia plant unit, iii) urea unit, iv) bagging and finishing unit, v) maintenance unit. These units discharge different types of pollutants containing ammonia, acid/alkali wash water, mud and aluminum hydroxide sludge, natural gas condensate, lubricating oil, urea condensate, diethanol amine potassium carbonate solution, vanadium oxides, urea dust etc.

Table 2.2 Emissions and Effluents of GUFFL and PUFFL

Nature of pollution	Type of pollutants
Emissions	Sulfuric acid fume, hydrogen sulfide
Air pollutions	Carbon monoxide, carbon dioxide, oxides of nitrogen, hydrocarbons, oxides of sulfur, urea dust, ammonia, dusts of sulfur
Effluents	Suspended solids, hydrochloric acid, sulfuric acid, sodium hydroxide, ammonium hydroxide, methanol, lubricating oil, acid/alkali wash water, chromium compounds, copper compounds, mud and alum sludge, steam condensate and hot water etc.

Source: GUFFL and PUFFL

2.3 Why does pollution matter

Pollution matters because it harms the environment on which people depend. The environment is not something distant and separate from our lives. The environment is everything that surrounds us that gives us life and health. Destroying the environment ultimately reduces the quality of our own lives—and that, most selfishly, is why pollution should matter to all of us.

2.3.1 How do we know when water is polluted

There are two main ways of measuring the quality of water. One is to take samples of the water and measure the concentrations of different chemicals that it contains. If the chemicals are dangerous or the concentrations are too great, we can regard the water as polluted. Measurements like this are known as **chemical indicators** of water quality. Another way to measure water quality involves examining the fish, insects, and other invertebrates that the water will support. If many different types of creatures can live in a river, the quality is likely to be very good; if the river supports no fish life at all, the quality is obviously much poorer. Measurements like this are called **biological indicators** of water quality.

2.4 Physical and Chemical Parameters

Chemical testing measures the concentration of dissolved or suspended substances in the water. Physical parameters, such as temperature, volume of flow, and velocity, can indicate

what type of aquatic organisms the stream will support. The physical and chemical make-up of a stream is affected by soil, geology, precipitation, vegetation and land use in the watershed. These parameters can change from day to day. They indicate conditions in the water at the time of sampling and can increase or decrease with the quantity of runoff.
Physical and chemical parameters help determine the type of pollution that may be affecting a waterway and can provide some clues as to the sources. Water quality is good if naturally occurring substances are present at levels that support aquatic life. Problems occur when activities alter natural levels or introduce substances that are toxic to aquatic life.

2.4.1 pH

Water (H_20) contains both hydrogen (H+) and hydroxyl (OH-) ions. The pH of water is a measurement of the concentration of H+ ions, using a scale that ranges from 0 to 14. A pH of 7 is considered "neutral", since concentrations of H+ and OH- ions are equal. Liquids or substances with pH measurements below 7 are considered "acidic", and contain more H+ ions than OH- ions. Those with pH measurements above 7 are considered "basic" or "alkaline," and contain more OH- ions than H+ ions. For every one unit change in pH, there is approximately a ten-fold change in acidity or alkalinity. Therefore, a pH of 4 is 10 times more acidic than a pH of 5. Similarly, a pH of 9 is 10 times more alkaline than a pH of 8 and 100 times more alkaline than a pH of 7. Pure deionized water is neutral, with a pH of 7. pH is an important property of natural waters influenced by the substances dissolved in the water and influencing chemical reactions and the ability of water to bring other substances into solution. A pH range of 6.0 to 9.0 appears to provide protection for the life of freshwater fish and bottom dwelling invertebrates

pH is defined as the negative logarithm of the activity of H^+ ions: $pH = -\log [H^+]$, Where $[H^+]$ is the concentration of H^+ ions in moles per liter

A range of pH 6.5 to pH 8.2 is optimal for most organisms.

- Most organisms have adapted to life in water of a specific pH and may die if it changes even slightly. The toxicity level of ammonia to fish, for example, varies tremendously within a small range of pH values.
- Acid rain containing nitric and sulferic acids can sharply lower the pH of a stream as the rain runs quickly off streets and roofs into creeks. Acidic water can cause heavy

metals such as copper and aluminum to be released into the water. Copper from worn automobile brake pads is often present in runoff.

- Rapids growing algae remove carbon dioxide from the water during photosynthesis, which can result in a significant increase in pH levels.

Runoff from agricultural, domestic, and industrial areas may contain iron, aluminum, ammonia, mercury or other elements. The pH of the water will determine the toxic effects, if any, of these substances. For example, 4 mg/l of iron would not present a toxic effect at a pH of 4.8. However, as little as 0.9 mg/l of iron at a pH of 5.5 can cause fish to die.

Synergy has special significance when considering water and wastewater treatment. The steps involved in water and wastewater treatment require specific pH levels. In order for coagulation (a treatment process) to occur, pH and alkalinity must fall within a limited range. Chlorination, a disinfecting process for drinking water, requires a pH range that is temperature dependent. pH levels between 7.2 to 8.5 are considered acceptable.

2.4.2 Temperature

It is important to monitor the temperature of our water bodies because the temperature of water influences the amount of oxygen available for aquatic organisms. Cold water holds more oxygen than warm water. Temperature also influences the rate of photo synthesis of aquatic plants. As water temperature increases, photosynthes is goes up, and the rate of decomposition and use of oxygen in creases. This can lead to degradation of the aquatic community.

Temperature also influences the sensitivity of organisms to toxic wastes, parasites, and disease. Bacteria grow faster in warm water, which could pose problems as Thermal pollution from storm water is added our water bodies Temperature of water is a very important factor for aquatic life. It controls the rate of metabolic and reproductive activities, and determines which fish species can survive. Temperature also affects the concentration of dissolved oxygen and can influence the activity of bacteria and toxic chemicals in water.

Temperature is important because it governs the kinds of aquatic life that can live in a stream. Fish, insects, zooplankton, phytoplankton, and other aquatic species all have a preferred temperature range. If temperatures get too far above or below this preferred range, the number of individuals of the species decreases until finally there are none.

Temperature also is important because it influences water chemistry. The rate of chemical reactions generally increases at higher temperatures, which in turn affects biological activity. Some compounds are also more toxic to aquatic life at higher temperatures.

Water temperature is sensitive to atmospheric temperature. It is influenced by the Sun's energy, water depth, water circulation, pump motor heat, and heat from other mechanical devices. Water temperature directly impacts the level of dissolved oxygen retention. A water temperature exceeding 75°F can inhibit the ability of fresh water to retain an acceptable level of dissolved oxygen.

2.4.3 Dissolved Oxygen

Dissolved oxygen (DO) refers to the volume of oxygen that is contained in water. Oxygen enters the water as rooted aquatic plants and algae undergo photosynthesis, and as oxygen are transferred across the air-water interface. The amount of oxygen that can be held by the water depends on the water temperature, salinity, and pressure. Gas solubility increases with decreasing temperature (colder water holds more oxygen). Gas solubility increases with decreasing salinity (freshwater holds more oxygen than does saltwater). Both the partial pressure and the degree of saturation of oxygen will change with altitude. Finally, gas solubility decreases as pressure decreases. Thus, the amount of oxygen absorbed in water decreases as altitude increases because of the decrease in relative pressure.

Dissolved oxygen may play a large role in the survival of aquatic life in temperate lakes and reservoirs during the summer months, due to a phenomenon called stratification (the formation of layers). Seasonal stratification occurs as a result of water's temperature-dependent density. As water temperatures increase, the density decreases. Thus, the sun-warmed water will remain at the surface of the water body (forming the epilimnion), while the denser, cooler water sinks to the bottom (hypolimnion). The layer of rapid temperature change separating the two layers is called the thermocline.

The introduction of excess organic matter may result in a depletion of oxygen from an aquatic system. Prolonged exposure to low dissolved oxygen levels (less than 5 to 6 mg/l oxygen) may not directly kill an organism, but will increase its susceptibility to other environmental stresses. Exposure to less than 30% saturation (less than 2 mg/l oxygen)

Dissolved Oxygen (DO) is the amount of gaseous oxygen that is dissolved in water. DO is considered low at levels less than 5mg/l and is lethal to many organisms at levels of less than 3mg/l. DO is probably the most significant indicator of aquatic health because DO is critical for aquatic animals such as fish that "breathe" oxygen through their gills.

Dissolved Oxygen

- Fish, invertebrates, plants, and aerobic bacteria all require oxygen for respiration.
- Much of the dissolved oxygen in water comes from the atmosphere. After dissolving at the surface, oxygen is distributed by current and turbulence. Algae and rooted aquatic plants also deliver oxygen to water through photosynthesis.
- The main factor contributing to changes in dissolved oxygen levels is the build-up of organic wastes. Decay of organic wastes consumes oxygen and is often concentrated in summer, when aquatic animals require more oxygen to support higher metabolisms.
- Depletions in dissolved oxygen can cause major shifts in the kinds of aquatic organisms found in water bodies.
- Temperature, pressure, and salinity affect the dissolved oxygen capacity of water. The ratio of the dissolved oxygen content (ppm) to the potential capacity (ppm) gives the percent saturation, which is an indicator of water quality.

DO levels below about 40% will not support most aquatic life. At least 60% is required to sustain fish populations. The DO level required to sustain sensitive species is around 80-90%.

2.4.4 Biochemical Oxygen Demand

When organic matter decomposes, microorganisms (such as bacteria and fungi) feed upon it and eventually it becomes oxidized (combined with oxygen). Biochemical oxygen demand is a measure of the quantity of oxygen used by these microorganisms in the aerobic oxidation of organic matter.

BOD is a measure of the amount of oxygen used up by biological and chemical processes in a sample of stream water over a 5-day. Oxygen in the water is consumed by process such as: the break down (rotting) of organic material; oxygen use by bacterial activity; and chemical reactions as chemicals are converted to more stable forms (e.g. the conversion of ammonia to nitrate).

BOD is calculated by measuring the oxygen level of the water on collection and then 5 days later after storage in the dark (to stop photosynthetic activity) at a constant temperature (usually 20 ^{o}C). The difference between the two values is the demand or consumption of oxygen by chemical and biological processes.

Biochemical Oxygen Demand

- Biochemical oxygen demand is a measure of the quantity of oxygen used by microorganisms (e.g., aerobic bacteria) in the oxidation of organic matter.
- Natural sources of organic matter include plant decay and leaf fall. However, plant growth and decay may be unnaturally accelerated when nutrients and sunlight are overly abundant due to human influence.
- Urban runoff carries pet wastes from streets and sidewalks; nutrients from lawn fertilizers; leaves, grass clippings, and paper from residential areas, which increase oxygen demand.
- Oxygen consumed in the decomposition process robs other aquatic organisms of the oxygen they need to live. Organisms that are more tolerant of lower dissolved oxygen levels may replace a diversity of more sensitive organisms.

$CBOD_5$ Carbonaceous Biochemical Oxygen Demand represents the amount of oxygen consumed by bacteria and other microorganisms while they decompose organic matter. It is a test used to determine the relative oxygen requirements of wastewaters, effluents, and polluted waters.

Calculation

For each test bottle meeting the 2.0-mg/L minimum DO depletion and the 1.0-mg/L residual DO, calculate BOD_5 as follows:

When dilution water is not seeded:

$$BOD_5, mg/L = \frac{D_1 - D_2}{P}$$

When dilution water is seeded:

$$BOD_5, mg/L = \frac{(D_1 - D_2) - (B_1 - B_2)f}{P}$$

Where:

D_1 = DO of diluted sample immediately after preparation, mg/L,

D_2 = DO of diluted sample after 5 d incubation at 20°C, mg/L,

P = decimal volumetric fraction of sample used,

B_1 = DO of seed control before incubation, mg/L

B_2 = DO of seed control after incubation mg/L and

f = ratio of seed in diluted sample to seed in seed control = (% seed in diluted sample)/(% seed in seed control).

If seed material is added directly to sample or to seed control bottles:

f = (volume of seed in diluted sample)/(volume of seed in seed control)

"Biochemical Oxygen Demand" (BOD). Because the test is performed over a five day period, it is often referred to as a "Five Day BOD", or a BOD_5.

2.4.5 Chemical Oxygen Demand

The concept of chemical oxygen demand (COD) is that all organic compounds, with but few exceptions, can be oxidized to carbon dioxide and water. In contrast with the BOD test, which measures only the biodegradable fraction, COD may measure toxic as well as biodegradable organic compounds. It is therefore applicable to many industrial wastes not readily analyzed for water quality factors by the sewage oriented BOD test (McGauhey, 1968)

2.4.6 Total Solids

The term "total solids" refers to matter suspended or dissolved in water or wastewater, and is related to both specific conductance and turbidity. Total solids (also referred to as total residue) are the term used for material left in a container after evaporation and drying of a water sample. **Total Solids** includes both **total suspended solids**, the portion of total solids retained by a filter and **total dissolved solids**, the portion that passes through a filter

2.4.7 Total Suspended Solids (TSS)

Total Suspended Solids (TSS) is solids in water that can be trapped by a filter. TSS can include a wide variety of material, such as silt, decaying plant and animal matter, industrial

wastes, and sewage. High concentrations of suspended solids can cause many problems for stream health and aquatic life.

High TSS can block light from reaching submerged vegetation. As the amount of light passing through the water is reduced, photosynthesis slows down. Reduced rates of photosynthesis causes less dissolved oxygen to be released into the water by plants. If light is completely blocked from bottom dwelling plants, the plants will stop producing oxygen and will die. As the plants are decomposed, bacteria will use up even more oxygen from the water. Low dissolved oxygen can lead to fish kills. High TSS can also cause an increase in surface water temperature, because the suspended particles absorb heat from sunlight. This can cause dissolved oxygen levels to fall even further (because warmer waters can hold less DO), and can harm aquatic life in many other ways.

The decrease in water clarity caused by TSS can affect the ability of fish to see and catch food. Suspended sediment can also clog fish gills, reduce growth rates, decrease resistance to disease, and prevent egg and larval development. High TSS in a water body can often mean higher concentrations of bacteria, nutrients, pesticides, and metals in the water. These pollutants may attach to sediment particles on the land and be carried into water bodies with storm water.

Total Suspended Solids (TSS) is the non-filterable portion of solids found in the water column. These contribute to the turbidity or cloudiness of the water and may clog fish gills, either killing them or reducing their growth rate. Suspended solids also reduce light penetration thus reducing the ability of algae to produce food and oxygen. TSS can also destroy fish habitat because suspended solids settle to the bottom and can eventually blanket the river bed. Suspended solids can smother the eggs of fish and aquatic insects, and can suffocate newly-hatched insect larvae. Suspended solids can also harm fish directly by clogging gills, reducing growth rates, and lowering resistance to disease. Changes to the aquatic environment may result in a diminished food sources, and increased difficulties in finding food. Natural movements and migrations of aquatic populations may be disrupted.

2.4.8 Total Dissolved Solids (TDS)

Total Dissolved Solids (TDS) are solids in water that can pass through a filter (usually with a pore size of 0.45 micrometers). TDS is a measure of the amount of material dissolved in

water. This material can include carbonate, bicarbonate, chloride, sulfate, phosphate, nitrate, calcium, magnesium, sodium, organic ions, and other ions. A certain level of these ions in water is necessary for aquatic life. Changes in TDS concentrations can be harmful because the density of the water determines the flow of water into and out of an organism's cells. However, if TDS concentrations are too high or too low, the growth of many aquatic lives can be limited, and death may occur.

Similar to TSS, high concentrations of TDS may also reduce water clarity, contribute to a decrease in photosynthesis, combine with toxic compounds and heavy metals, and lead to an increase in water temperature TDS is used to estimate the quality of drinking water, because it represents the amount of ions in the water. Water with high TDS often has a bad taste and/or high water hardness, and could result in a laxative effect.

A certain level of these ions in water is necessary for aquatic life. Changes in TDS concentrations can be harmful because the water density determines the flow of water in and out of an organism's cells. If TDS concentrations are too high or too low, growth of aquatic life may be limited and death may occur. High concentrations of TDS may also reduce water clarity, contribute to a decrease in photosynthesis, lead to an increase in temperature, and transport toxic compounds and heavy metals. Rainwater contains less than 10 ppm TDS. Rivers may contain between 100 and 2,000 ppm. Maximum allowable levels range from 750 ppm to 1500 ppm. The specific allowable level is determined by the type of waterway – warm or cold water stream and the type of fish it should support.

2.4.9 Ammonia

In nature, ammonia is formed by the action of bacteria on proteins and urea. Ammonia is toxic to fish and aquatic organisms, even in very low concentrations. When levels reach 0.06 mg/L, fish can suffer gill damage. When levels reach 0.2 mg/L, sensitive fish like trout and salmon begin to die. As levels near 2.0 mg/L, even ammonia-tolerant fish like carp begin to die. Ammonia levels greater than approximately 0.1 mg/L usually indicate polluted waters. The danger ammonia poses for fish depends on the water's temperature and pH, along with the dissolved oxygen and carbon dioxide levels. Remember, the higher the pH and the warmer the temperature, the more toxic the ammonia. Also, ammonia is much more toxic to fish and aquatic life when water contains very little dissolved oxygen and carbon dioxide.

- Nitrogen occurs in natural waters as nitrate (NO_3), nitrite (NO_2), ammonia (NH_3), and organically bound nitrogen.
- As aquatic plants and animals die, bacteria break down large protein molecules containing nitrogen into ammonia. Ammonia is then oxidized by specialized bacteria to form nitrites and nitrates.
- Sewage is the main source of ammonia added by humans to rivers. The ammonia arises mostly from the hydrolysis of urea in urine, but additional ammonia is generated by the decomposition of other nitrogenous materials in sewage.

In a flowing stream, the presence of ammonia in high concentrations indicates recent pollution. Sewage may be entering the water somewhere in the vicinity.

2.5 Biological Parameters

Biological monitoring provides an indication of stream health over time, because it measures aquatic organisms and their responses to changes in their environment. The presence, diversity, and abundance of certain types of organisms can provide information on stream health, because they react differently to changes in water quality. Biological surveys can be used to identify the impact of pollution and pollution control activities, to rank stream health, and identify water quality trends. The most common organisms studied are fish, algae, and macro invertebrates. This study focuses on macro invertebrates.

2.5.1 Total Coli form and Fecal Coli form

Total coliform bacteria are a collection of relatively harmless microorganisms that live in large numbers in the intestines of man and warm- and cold-blooded animals. They aid in the digestion of food. A specific subgroup of this collection is the fecal coliform bacteria, the most common member being Escherichia coli. These organisms may be separated from the total coliform group by their ability to grow at elevated temperatures and are associated only with the fecal material of warm-blooded animals.

The presence of fecal coliform bacteria in aquatic environments indicates that the water has been contaminated with the fecal material of man or other animals. At the time this occurred, the source water may have been contaminated by pathogens or disease producing bacteria or

viruses which can also exist in fecal material. Some waterborne pathogenic diseases include typhoid fever, viral and bacterial gastroenteritis and hepatitis A.

Fecal coli forms are bacteria that are naturally occurring in the digestive tracts of human and other warm blooded animals. Fecal coli form itself does not cause disease, but it may indicate the presence of other bacteria that may be harmful. Fecal coli form mis routinely tested because it is a safe, inexpensive way to determine if other bacteria are present. If fecal coli form counts are high; it is likely that other organisms are present. It is the second Occurring organisms that have been linked to typhoid fever, hepatitis, gastroenteritis, dysentery, and ear infections.

The coliform bacteria group consists of several genera of bacteria belonging to the family *enterobacteriaceae*. These mostly harmless bacteria live in soil, water, and the digestive system of animals. Fecal coliform bacteria, which belong to this group, are present in large numbers in the feces and intestinal tracts of humans and other warm-blooded animals, and can enter water bodies from human and animal waste. If a large number of fecal coliform bacteria (over 200 colonies/100 milliliters (ml) of water sample) are found in water, it is possible that pathogenic (disease- or illness-causing) organisms are also present in the water.

Fecal coliform bacteria are microscopic organisms that live in the intestines of warm-blooded animals. They also live in the waste material, or feces, excreted from the intestinal tract. When fecal coliform bacteria are present in high numbers in a water sample, it means that the water has received fecal matter from one source or another. Although not necessarily agents of disease, fecal coliform bacteria may indicate the presence of disease-carrying organisms, which live in the same environment as the fecal coliform bacteria.

Coliforms are a broad class of bacteria found in our environment, including the feces of man and other warm-blooded animals. The presence of coliform bacteria in drinking water may indicate a possible presence of harmful, disease-causing organisms.

2.5.2 Algae

- Algae, also known as phytoplankton, are tiny, single-celled plants.
- The abundance of algae is controlled by factors such as light, salinity, water temperature, and nutrient levels. An algal population explosion is known as a "bloom."
- High concentrations of algae will raise the dissolved oxygen concentration during the day while algae photosynthesize, but oxygen concentrations may drop off steeply overnight as algae consume oxygen or decompose. Aquatic animals may suffocate as a result.
- The photosynthetic process may also raise the pH to uncomfortable levels. Decaying algae can also cause odor problems and attract flies.
- Urban creeks, which are often poorly shaded and well feed with runoff from fertilized yards and home car washes, are especially susceptible to algal blooms.

2.6 Environmental Quality Standards (EQS)

The Environmental Quality Standards (EQS) of relevant parameters set out by the DOE (DOE, 1991) for fishing, recreational and irrigation water as shown in Table 2.3. The Ministry of Environment and Forest (MOEF) published EQS in a Gazette (Bangladesh Gazette, Addendum, on 28 August in 1997 (MOEF, 1997) for environmental protection and management in the working level. Besides, there are several guidelines provided by different countries or organizations like United State Environmental Protection Agency (USEPA), World Health Organization (WHO), European Union (EU), Canada and Russia. Table 2.5 describes the following limits of different inorganic water quality parameters for drinking waters specified by USEPA, WHO and Bangladesh. Table 2.6 describes maximum allowable concentration of water quality variables for drinking provided by WHO, EU, Canada and Russia. Table 2.7 describes maximum allowable concentrations of water quality variables for fisheries and other aquatic lives.

Table 2.3 EQS of some relevant water quality parameters, DOE 1991

Parameters	Recreational	Fishing	Irrigation
Total Alkalinity, mg/l	NYS	70-100	NYS
Ammonia (NH_3), mg/l	2	0.025	3
Ammonical Nitrogen (as N), mg/l	NYS	1.2	15
BOD (ultimate), mg/l	3	6	10
Chloride (as Cl), mg/l	600	600	600
COD, mg/l	4	NYS	NYS
Chromium, mg/l	NYS	0.05	NYS
Coliform (total), Nos/100 ml	NYS	NYS	10
DO, mg/l	4-5	4-6	5
Nitrate (as N), mg/l	NYS	NYS	NYS
pH	6-9.5	6.5-8.5	6-8.5
SS, mg/l	20	25	NYS

Source: Kamal, 1996

Table 2.4 EQS of some relevant water quality parameters, DOE 1997

Parameters	Recreational	Fishing	Irrigation
pH	6.5-8.5	6.5-8.5	
BOD (ultimate), mg/l	≤ 3	≤ 6	
DO, mg/l	≥ 5	≥ 5	≥ 5
Total Coliform (No./100ml)	≤ 200	≤ 5000	≤ 1000
Ammonical Nitrogen (as N), mg/l	-	≤1.2	-
Electrical Conductivity (μmho/cm)	-	-	2250

Source: Bangladesh Gazette, Addendum, 28th August 1997

Table 2.5 Drinking water quality standards (Source: Ahmed, et al, 2001)

Parameter	USEPA (2000)	WHO (1993)	Bangladesh (GoB,1997)
Aluminium (mg/l)	0.05-0.20	0.20	0.1(0.2)
Antimony (mg/l)	0.006	0.005	
Arsenic (mg/l)	0.01	0.01	0.05
Barium (mg/l)	2.0	0.70	1.0
Bromide (mg/l)	10		10
Calcium (mg/l)			75(200)
Cadmium (mg/l)	0.005	0.003	0.01
Chloride (mg/l)	250	250	200(600)
Chromium (mg/l)	0.10	0.05	0.05
Copper (mg/l)	1.31	0.20	1.5
Fluoride (mg/l)	2.0	1.50	1.0
Hardness as $CaCo_3$ (mg/l)	100-500		200-500
Iron (mg/l)	0.30	0.30	0.30(1.0)
Lead (mg/l)	0.015	0.01	0.10
Manganese (mg/l)	0.10	0.1-0.05	0.10(0.5)

Nickel (mg/l)	0.10	0.02	
Nitrate (mg/l)	10	50	10
Nitrite (mg/l)	1		
Phosphate (mg/l)	0.005		6.0
pH	6.5-8.5	6.5-8.5	6.5-8.5
Selenium (mg/l)	0.05	0.01	
Silver (mg/l)	0.10		
Sodium (mg/l)		200	
Sulfate (mg/l)	250	250	400
TDS (mg/l)	400-500	1000	500(1500)
Zinc (mg/l)	5.0	3.0	5(15)

Bangladesh standard values are given as maximum desirable concentration with maximum permissible concentration in parentheses.

Table 2.6 Maximum allowable concentrations of water quality variables for drinking (Source: Chapman, 1996)

Use Variable	WHO	EU	Canada	USA	Russia
Colour (TCU)	15	20 Pt-Co	15	15	20
Total dissolved solids (mg/l)	1000		500	500	1000
Total suspended solids (mg/l)					
Turbidity (NTU)	5	4 JTU	5	0.5-1.0	
pH	<8	6.5-8.5	6.5-8.5	6.5-8.5	6.0-9.0
Dissolved Oxygen(mg/l)					4.0
Ammonical Nitrogen (as N), mg/l					2.0
Ammonium (NH_3), mg/l		0.50			2.0
Nitrate as N(mg/l)			10	10	
Nitrate(mg/l)	50	50			45
Nitrite as N(mg/l)			1.0	1.0	
Nitrite(mg/l)	3	0.1			3.0
Phosphorus(mg/l)	3	5.0			
BOD(mg/l O_2)					3.0
Sodium(mg/l)	200	150			
Chloride (mg/l)	250	25	250	250	350
Chlorine(mg/l)	5				
Sulfate(mg/l)	250	250	500	250	500
Sulphide(mg/l)			0.05		
Fluoride (mg/l)	1.5	1.5	1.5	2.0	<1.5
Boron(mg/l)	0.30	1.0	5.0		0.30
Cyanide(mg/l)	0.07	0.05	0.2	0.2(PP)	0.07
Aluminium (mg/l)	0.20	0.2			0.50
Arsenic (mg/l)	0.01	0.05	0.05	0.05	0.01
Barium(mg/l)	0.7	0.1	1.0	2.0	0.7
Cadmium (mg/l)	0.003	0.005	0.005	0.005	0.003
Chromium(mg/l)	0.05	0.05	0.05	0.10	0.05
Cobalt(mg/l)					0.10
Copper(mg/l)	2	0.1-3.0	1.0	1	2.0
Iron (mg/l)	0.3	0.2	0.3	0.3	0.30
Lead (mg/l)	0.01	0.05	0.05	0.015	0.01
Manganese (mg/l)	0.5	0.05	0.05	0.05	0.5

Mercury (mg/l)	0.001	0.001	0.001	0.002	0.001
Nickel(mg/l)	0.02	0.05			0.02
Selenium(mg/l)	0.01	0.01	0.01	0.05	0.01
Zinc(mg/l)	3	0.1-5.0	5.0	5	5.0
Oil and petroleum products (μg/l)		0.01			0.10
Total pesticides(μg/l)		0.5	100		
Aldrin & dieldrin (μg/l)	0.03		0.7		
DDT(μg/l)	2		30.0		2.0
Lindane(μg/l)	2		4.0	0.2	2.0
Methoxychlor(μg/l)	20		100	40	
Benzene(μg/l)	10			5	
Penta chlorophenol	9			10	10
Phenols(μg/l)		0.5	2		1.0
Detergents(μg/l)		0.2		0.5	0.5
Faecal Coliforms (E.Coli) (No. per 100ml)	0	0	0		0
Total Coliforms (No. per 100 ml)	0		10	1	0.30

Table 2.7 Maximum allowable concentrations of water quality variables for Fisheries and other aquatic lives (Source: Chapman, 1996)

Use Variable	EU	Canada	Russia
Total suspended solids (mg/l)	25	10	
pH	6.0-9.0	6.0-9.0	
Dissolved Oxygen(mg/l)	5.0-9.0	5.0-9.0	4.0-6.0
Ammonical Nitrogen (as N), mg/l	0.005-0.025	1.37-2.2	0.05
Ammonium (NH_3), mg/l	0.04-1.0		0.50
Nitrate(mg/l)			40
Nitrite(mg/l)	0.01-0.03	0.06	0.08
BOD (mg/l)	3.0-6.0		3.0
Sodium(mg/l)			120
Chloride (mg/l) (mg/l)			300
Chlorine(mg/l)			
Sulfate(mg/l)		0.002	100
Fluoride (mg/l)			0.75
Cyanide(mg/l)		0.005	0.05
Aluminium (mg/l)		0.005-0.1	
Arsenic (mg/l)		0.05	0.005
Cadmium (mg/l)		0.0002-0.0018	0.02-0.005
Chromium(mg/l)		0.02-0.002	0.01
Cobalt(mg/l)			0.001
Copper(mg/l)	0.005-0.112	0.002-0.004	0.10
Iron (mg/l)		0.30	0.10
Lead (mg/l)		0.001-0.007	0.01
Manganese (mg/l)			0.00001
Mercury (mg/l)		0.0001	0.01
Nickel(mg/l)		0.025-0.12	0.0016
Selenium(mg/l)		0.001	0.01

Zinc(mg/l)		0.03	0.05
Oil and petroleum products(µg/l)			
Aldrin & dieldrin (µg/l)		4 ng/l	
DDT(µg/l)		1 ng/l	
Benzene(µg/l)		300	
Phenols(µg/l)		1.0	1.0
Detergents(µg/l)			

Table 2.8 Industrial /Project Effluent Standards (Source: ECR'97)

Parameters	Discharge into in-land water	Discharge into publis sewer	Discharge on irrigated land
Ammonia (NH_3)	5	5	15
Ammonical Nitrogen (as N), mg/l	50	75	75
Arsenic (mg/l)	0.2	0.05	0.2
BOD_5 @20°C (mg/l)	50	250	100
Boron(mg/l)	0.2	2	2
Cadmium (mg/l)	0.05	0.5	0.5
Chloride (mg/l) (mg/l)	600	600	600
Chromium(as Cr6+) (mg/l)	0.1	1	1
Chromium (Total)(mg/l)	0.5	1	1
COD(mg/l)	200	400	400
Copper(mg/l)	0.5	3	3
Cyanide(mg/l)	0.1	2.0	0.2
Dissolved Oxygen(mg/l)	4.5-8	4.5-8	4.5-8
Electro-conductivity (Mmho/cm)	1200	1200	1200
Fluoride (mg/l) (as F-)	2	15	10
Iron (mg/l)	2	2	2
Total Kjeldahl nitrogen (mg/l)	100	100	100
Lead (mg/l)	0.1	1	0.1
Manganese (mg/l)	5	5	5
Mercury (mg/l)	0.01	0.01	0.01
Nickel(mg/l)	1	2	1
Nitrate as N(mg/l)	10	NYS	10
Oil and grease(mg/l)	10	20	10
pH	6-9	6-9	6-9
Phenolic compounds(mg/l)	1	5	1
Phosphorous (mg/l)	8	8	15
Selenium(mg/l)	0.05	0.05	0.05
Total suspended solids (mg/l)	150	500	200
Sulfide(mg/l)	1	2	2
Total dissolved solids (mg/l)	2100	2100	2100
Temperature (°C)	40*/45**	40*/45**	40*/45**
Total solids(mg/l)	2100	2100	2100
Radioactive materials@			
Zinc(mg/l)	5	10	10

Note: *Summer/** winter; @ To be set by BAEC; NYS= Not yet set

2.7 Summary of Previous Works

Some potential studies were done on impact of effluent on water quality and environment. The summary of some of them is described briefly in the following sections.

Kalam (1968) investigated the water quality of the river Buriganga near Chadnighat in the year 1967 to 1968. Kalam observed that, for making potable the water of the Buriganga is required to be treated for the removal of turbidity, hardness, alkalinity, soluble iron, manganese etc.

Islam (1977) investigated the water quality of various rivers in and around Dhaka city. He noticed that the surface waters are being increasingly polluted with the passage of time. He also recommended that water from both Buriganga and Sitalakhya could be treated effectively and economically for Dhaka water supply.

Tarikuzzaman (1998) assessed the impact of Jamuna fertilizer industry on the surrounding environment. He found that the concentration of pH, conductivity, BOD_5, COD, SS, TS ammonia, urea sulphate, sulphide, heavy metals (Cu, Zn, Pb, Mn) and turbidity occasionally exceed the respective permissible values. As a result fish population of the Jamuna River near the factory reduced to a great extent compared to that before installation of the industry.

Islam (2004) estimated industrial pollution load in Bangladesh. He noticed that the BOD load from the entire industrial sector has been estimated at around 34,000 metric ton for the year 1991-92 and about 28,000 metric ton for the year 1995-96. The total TSS load from all industrial sectors have been estimated to be around 40,000 metric ton for the year 1991-92 and about 30,000 metric tons for the year 1995-96. The total toxic-chemical pollution load in Bangladesh has been estimated to be about 37000 MT and 41000 MT in 1991-92 and 1995-96, respectively. Estimated total toxic-metal release in the country in 1991-92 and 1995-96 is approximately 7250 MT and 7500 MT, respectively.

Institute of Water Modelling (2004) conducted a study to investigate alternate location of the intake of Saidabad water treatment plant. Results of the study showed that the DO level in present condition (0.6 mg/l) is far below the critical DO level (4 mg/l) and it will continue to decrease with increasing waste load in future. Norai khal, DND canal and Majheepara khal, Tanbazar khal, Killarpul khal, Kalibazar khal and B.K Road khal from Narayanganj had been identified as the major pollutant sources affecting the water quality at Sarulia.

Sarkar (2005) assessed surface water for Sylhet city. He noticed that the physical, chemical and biochemical characteristics of water of the river Surma and the river Kushiyara were determined through extensive laboratory tests. Except suspended solids and turbidity all other parameters have higher concentrations in the dry season comparing to the wet season for both the rivers as high flows in wet season provide better dilution of pollutants. Huge amount of surface and agricultural runoff and bank erosion increases suspended solids and turbidity in the wet season. It is evident from experimental results of water quality parameters that both the rivers can be used as source of water for fishing, industrial and irrigation purpose according to Bangladesh standards of inland surface water. However, the test results of coliform exceed the limit of Bangladesh standard for recreational use. Comparing to the surface water bodies around Dhaka city it can be concluded that the degree of pollution of the Surma and the Kushiyara is not yet high and can be used as an alternative source of water supply instead of ground water for Sylhet City Corporation.

Magumdar (2005) assessed the water quality around Dhaka city. He observed that in consideration of drinking standards, the river water is contaminated by several parameters, which include organic matter, suspended solids and microorganisms. Ammonia level in different reaches of the river system is well above the permitted value specified in the United State Environmental Protection Agency (USEPA) guideline to avoid toxic effect on fishes. Concentrations of Nitrate (N03-), Phosphate (POl-), Zinc (2n), Chromium (Cr), Lead (Pb) and Mercury (Rg) in the river system are well below the allowable limits specified in different Environmental Quality Standards (EQS).

Alam (2006) characterized the liquid waste of Natural Gas Fertilizer Factory Limited and to identify any changes of water quality of Kushiara River due to discharge of industrial effluent from NGFFL. He observed that Dissolved solid contents of the lagoons were within the limit, but suspended solid contents exceeded the Bangladesh Standards for industrial eftluent. COD and BODs were well below the Bangladesh Standard. Dissolved Oxygen of the wastewater was found to be between 2.0 to 3.0 mg/l, which do not satisfy the standard (4.5 -8 mg/l). Oil and grease concentrations were found in the range of28 to 68 mg/l, much higher than the standard (10 mg/l) for discharge into the inland surface water. Chromium and nitrate were found to be slightly higher than the standard limit for some samples. Ammonia nitrogen concentration was very high in lagoon I, which is being directly discharged into the Kushiara River. River water quality was analyzed in the month of December. Ammonia nitrogen was

found to be 0.44 mg/l and 0.18 mg/l at the 300 yards and 1500 yards downstream of the eftluent discharge point, respectively. The efficiency of lagoon 2 was analyzed and found that the lagoon 2 is not efficiently reducing ammonia.

World Bank (2007) conducted a study on industrial environmental compliance and pollution control in greater Dhaka. World Bank noticed the following observations: 1) Except for very few, most of the industries in the Clusters either do not have or have rudimentary/inadequate effluent treatment facilities. As a result, the effluent quality in almost all cases violates the Environment Quality Standards (EQS) of Bangladesh. 2) From water sample analyses at 14 locations in the river system of Dhaka watershed, it has become evident that in 12 locations the BOD and DO levels are beyond acceptable limits. This implies that the surface water quality situation in Dhaka watershed is generally in unacceptable conditions. 3) Groundwater over abstraction caused unusual declining rate of water level and developed mining situation which accelerates force recharge and enhances the risk of aquifer contamination from peripheral polluted rivers system and industrial effluent of the Dhaka watershed. 4) The elevated concentration of heavy metals and the influent character of the city river systems allow the mobilization of metal ions and their transport into the nearby section of Upper Dupi Tila aquifer system and subsequently migration with the groundwater flow towards the DWASA wells. There is possibility of infiltration of polluted water from the drains and ponds directly to the aquifer (through the overlying clay layer) and with the groundwater flow towards the production wells.

CHAPTER 3

SAMPLING AND ANALYSIS

3.1 Introduction

In Bangladesh, industrial units are mostly located along the banks of the rivers. There are obvious reasons for this such as provision of transportation for incoming raw materials and outgoing finished products. Unfortunately as a consequence, industrial units drain effluents directly into the rivers without any consideration of the environmental degradation. The most problematic industries for the water sector are textiles, tanneries, pulp and paper mills, fertilizer, industrial chemical production and refineries. A complex mixture of hazardous chemicals, both organic and inorganic, is discharged into the water bodies from all these industries usually without treatment.

3.2 Ghorasal and Polash Urea Fertilizer Factories

The seven (one private) urea fertilizer plants currently operating in Bangladesh are all under the control of BCIC, a state corporation. Most of them are located on rivers, into which they discharge their wastewater. Most of them use natural gas as the basic feedstock; include both ammonia and urea facilities; and operate on selfgenerated electricity. Polash (N-23° 59′ 12″, E-90° 38′ 27.05″) and Ghorasal (N-23° 59′ 8.9″, E-90° 38′ 32.8″) Urea fertilizer factories are also situated on the bank of the river Lakhya which flows around the capital city of Bangladesh. These are under Narsinghdi district of Bangladesh. These two plants were built in different eras: GUFF with Japanese assistance in 1968 and PUFF with Chinese assistance in 1985. Technologically, however, they are approximately at parity. The Chinese design closely reflects the two-decades-old Japanese design. The major water pollutants are the same: BOD, pH, ammonia, urea, alum sludge, oil, and grease. The two plants also share a first-stage treatment lagoon, which was constructed by GUFF in 1980. Both factories use the lagoon to dilute the effluent with wastewater from their staff colonies. Polash and Ghorasal Urea Fertilizer Factories produce 305 and 1100 tons urea per day respectively. As a result a huge amount of effluent produced from these factories, but unfortunately most of the effluent is discharged into the Lakhya River without treatment and patial treatment. A large number of peoples depend on Lakhya River for their household, industrial and other purposes. However, the water quality of the Lakhya River is deteriorating day by day due to human

activities and industrial effluents, which are built up on its bank. So it is of vital importance to monitor and simulate the water quality parameters of the Lakhya River to ascertain whether the water is still suitable for various uses.

3.3 Sample and Sampling

Samples of waste water collected from different sources should fairly represent the body of the waste from which they were collected. There are three main methods of sampling viz. grab sampling, composite sampling and continuous monitoring sampling. However sampling for ordinary chemical analysis requires no specific methods and precautions other than collecting it in a clear glass container of good quality having glass stopper. Samples for bacterial analysis must be collected in a sterilized bottle with stopper. For this study grab-sampling method was employed and samples were collected in plastic containers with stopper from 20 cm below the top of the water surface from the sampling point 2,3,4,5, 7 and mid point of Lakhya River at the sampling point 1, 6, 8 and 9.

Water quality is a value judgment that is related to the intended purpose of the water body and based on the physical, chemical, and/or biological attributes of the water body. Water quality may be defined by a single or multiple characteristics. The study requires physico-chemical characteristics of the effluent discharged from the factories and the river water quality data of the upstream and downstream side of the discharged point over a certain period of time. This study is based on the data which was obtained by the test performed at the Environmental Engineering workshop in the Civil Engineering Department, BUET, Dhaka. For this purpose the tests were performed at June, 2007 to July, 2007.

3.3.1 Selection of Sampling Site

Ideal sampling sites are seldom present. Selection of a sampling site should consider the following characteristics and the importance of each to the study objectives and how each may affect the quality of the sampling results, based on study objectives. In locating sampling stations or points on a river it was necessary to determine a suitable point on the longitudinal section, taking into consideration the distance from the river bank and the depth, usually measured from the water sample.

In selecting sampling location the following three criteria was the basic practical consideration:

1. The sampling points were located at points where the measured parameters show a distinct gradient.
2. It is not the water quality at the sampling point, which is of interest, but that of the total water body. Sampling points selected was therefore the representative, as far as possible, of a whole water body.
3. Some practical constraints were considered, for example, river traffic condition or the access to the sampling station.

The sampling points which were selected in this study were as follows

Sampling point-1: This point is located upstream of the fertilizer factories. Water sample was collected from this point was unaffected by the effluent of the fertilizer factories (Polash and Ghorasal).

Sampling point-2: This is the lagoon where effluent discharged from the fertilizer factories (Polash and Ghorasal) was retained. Ultimately this effluent was discharged into the Lakhya River through pump and this point is very close to the pump.

Sampling point-3: This is the drain of the Polash urea fertilizer factory. The treated effluent of this factory was discharged through this drain. The performance of the treatment process of Polash factory was evaluated from this point.

Sampling point-4: The sample in this drain was the combination of treated effluent discharged from the Polash urea fertilizer factory, untreated effluent discharged from Lagoon and household effluent discharged from residential area of the fertilizer factories. This drain discharged effluent into the Lakhya River.

Sampling point-5: Untreated effluent of Ghorasal Urea Fertilizer Factory was discharged through this point.

Sampling point-6: This point is 1000m downstream from the sampling point-1. The water samples at this point were affected by the untreated effluent of Ghorasal Urea Fertilizer Factory.

Sampling point-7: This is the drain of the Ghorasal urea fertilizer factory. The treated effluent of this factory was discharged through this drain. This drain discharged effluent into the Lakhya River. The performance of the treatment process of Ghorasal factory was evaluated from this point.

Sampling point-8: This point is 538m downstream from the sampling point-6. The water samples of this point were totally affected by both the fertilizer factories (Polash and

Ghorasal). Combined effects of effluent from both the factories on the Lakhya were evaluated from investigation at this point.

Sampling point-9: This point is 514m downstream from the sampling point-8. The water samples of this point were also totally affected by both the fertilizer factories (Polash and Ghorasal). This point was necessary to evaluate the impact of effluent from fertilizer factories along the length of the river.

Polash and Ghorasal urea fertilizer factories are situated on the left bank and there are residential areas on the right bank of the Lakhya River

Wastewater sampling and flow measurements were carried out at nine points (Table-1).

Table-1: Detail of wastewater sampling and flow measurement locations

Wastewater sampling station	Sampling point	Position	Number of samples were taken (one sample/week)	Number of flow measurements were taken (one measurement/week)
Polash	1	N-23° 59′ 48.06″ E-90° 38′ 16.12″	5	Secondary source (IWM)
Polash	2	N-23° 59′ 22.2″ E-90° 38′ 52″	5	5
Polash	3	N-23° 59′ 12″ E-90° 38′ 27.05″	5	5
Polash	4	N-23° 59′ 8.9″ E-90° 38′ 32.8″	5	5
Polash	5	N-23° 59′ 22.2″ E-90° 38′ 13.8″	5	5
Polash	6	N-23° 59′ 19.68″ E-90° 38′ 8.33″	5	Secondary source (IWM)
Polash	7	N-23° 59′ 16.6″ E-90° 38′ 13.2″	5	5
Polash	8	N-23° 59′ 3.35″ E-90° 38′ 1.95″	5	Secondary source (IWM)
Polash	9	N-23° 58′ 47.83″ E-90° 37′ 56.67″	5	Secondary source (IWM)
		Total	**45 nos.**	

Comprehensive water quality sampling and flow measurement were carried out at several stations in the Lakhya River system. Waste water sampling was also carried out at Polash and Ghorasal Urea Fertilizer Factories. Locations of water/waste water quality sampling and discharge measurement stations are shown in **Figure-3.1**

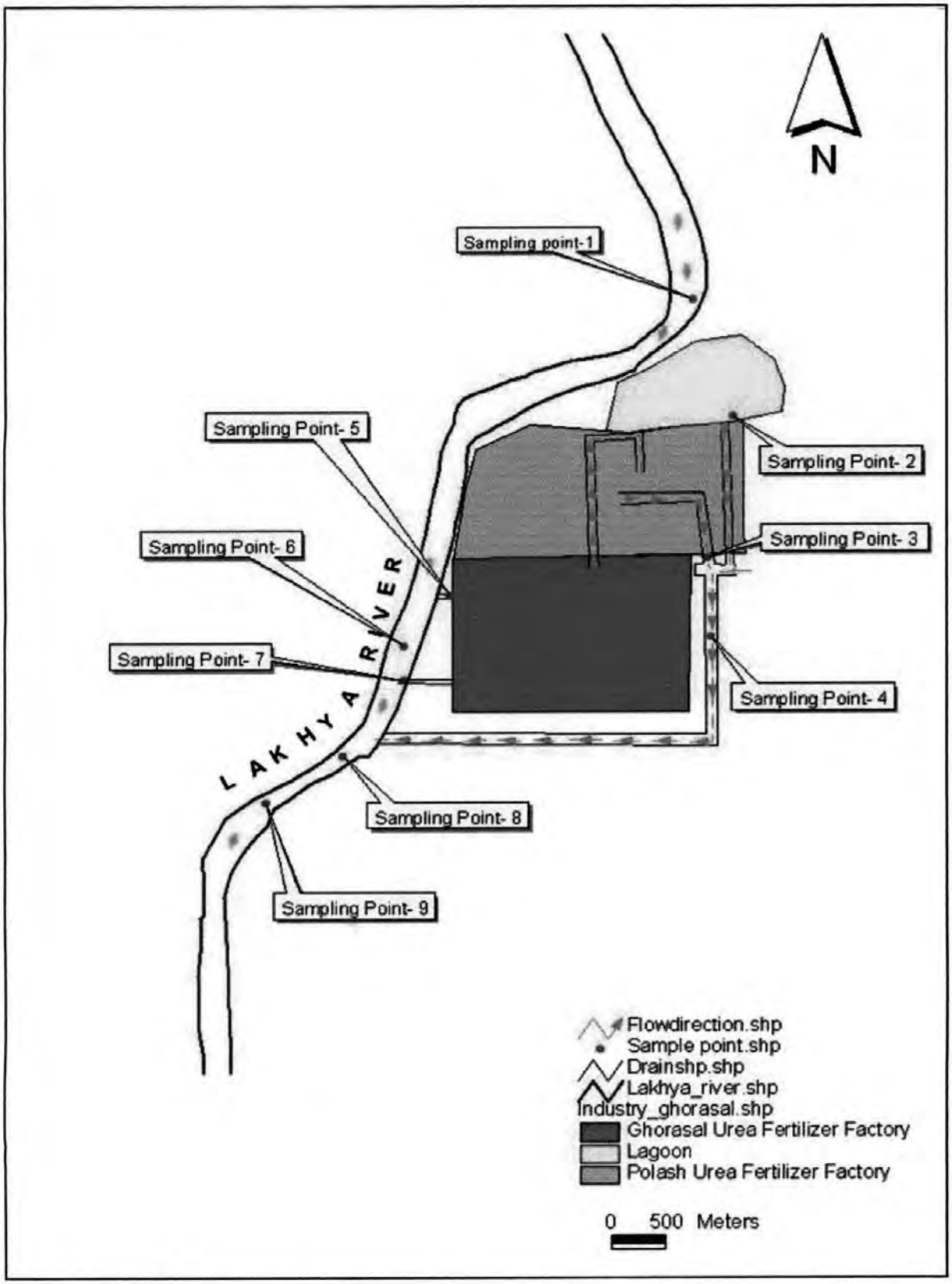


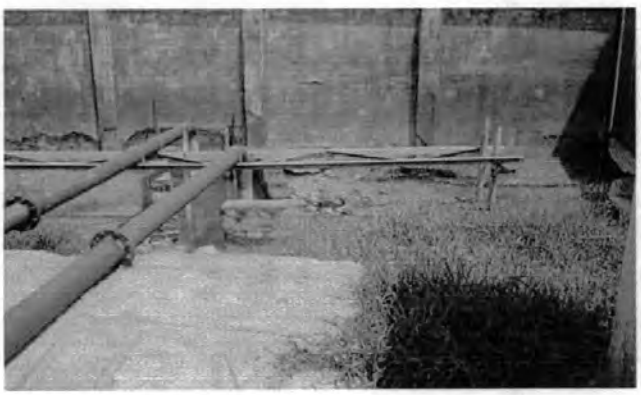
Figure 3.1: Sampling point locations

Photograph 3.1: Untreated effluent discharged in to the Lagoon through this drain

Photograph 3.2: Untreated effluent from Polash and Ghorasal urea fertilizer factories combined at this point

Photograph 3.3: Sampling point-2 (Lagoon)

Photograph 3.4: Sampling point-2 (Lagoon)



Photograph 3.5: Effluent discharged from Lagoon through these pump

Photograph 3.6: Effluent discharged from Lagoon through this drain

Photograph 3.7: Sampling point-3

Photograph 3.8: Effluent of sampling point-2 and 3 combined at this point

Photograph 3.9: House hold effluent discharged through this drain

Photograph 3.10: House hold effluent, Effluent of sampling point-2 and 3 combined at this point

Photograph 3.11: Sampling point-5 (Untreated effluent discharged into the Lakhya River through this point in June-July, 2007)

Photograph 3.12: Sampling point-5 (Untreated effluent discharged into the Lakhya River through this point in March-April, 2008)

Photograph 3.13: Sampling point-7

Photograph 3.14: Measurement of pH, DO, Temperature at the sampling site

Photograph 3.15: Water quality sampling at the Lakhya River

Photograph 3.16: Removing air bubble from water quality sampling at the Lakhya River

3.3.2 Water and wastewater sampling

The positions of Dissolved Oxygen (DO) measurement and Water quality (WQ) sample collection were determined with the aid of a hand-held GPS. The depths of the rivers at each of the sections were measured by means of weight, rope and measuring tape. The weight were attached to the end of the rope and lowered at the particular section till it hit the riverbed. Pumped river water was collected in a metallic cylinder and the sampling bottle was subsequently immersed to remove air bubbles. Once the sampling bottle was filled up with the river water, it was sealed and preserved in an icebox.

3.3.2 Discharge measurements

Discharge measurements were carried out at Polash and Ghorasal Urea Fertilizer Factories. It were carried out at sampling point 2, 3, 4, 5, 7 by float velocity method and at sampling point 1, 6, 8, 9 of Lakhya River from Institute of Water Modelling.

3.4 Analyses of samples

Wastewater samples were tested at the Environmental Engineering workshop of Bangladesh University of Engineering and Technology (BUET) for analyses of Total Ammonia (NH_3-N and NH_4-N), BOD_5, COD, TS, TSS, and TDS. Temperature, pH and DO were tested and flow measured on the site. The impact of fertilizer factories on the Lakhya River were evaluated by the analyses of water sample of sampling point 1, 6, 8 and 9. The amounts of waste discharged from the factories were evaluated by the analyses of wastewater sample and discharge measurement of sampling point 2, 3, 4, 5 and 7.

Table 3.1 Parameters tested for different wastewater samples

Sampling point	Parameters tested									
	NH_4-N	NH_3-N	pH	Temp	DO	BOD_5	COD	TS	TSS	TDS
1	x	x	x	x	x	x	x	x	x	x
2	x	x	x	x	x	x	x	x	x	x
3	x	x	x	x	x	x	x	x	x	x
4	x	x	x	x	x	x	x	x	x	x
5	x	x	x	x	x	x	x	x	x	x
6	x	x	x	x	x	x	x	x	x	x
7	x	x	x	x	x	x	x	x	x	x
8	x	x	x	x	x	x	x	x	x	x
9	x	x	x	x	x	x	x	x	x	x

Table-3.2 Different methods of testing sample

Parameters	Method of Testing	Instrument used
pH	Electrometric	pH meter (Hach)
Temperature	Electrometric	Temperature meter
DO	Electrometric	DO meter
BOD_5	Standard Method	Standard methods for Analysis of water and wastewater, 20th Edition, APHA, AWWA, WEE, 1998
COD (Dichromate value)	Reactor Digestion Method	Spectrophoto meter (Hach DR/4000U)
NH_3-N	Nessler Method	Spectrophoto meter (Hach DR/4000U)
NH_4-N	Nessler Method	Spectrophoto meter (Hach DR/4000U)
TS	Standard Method 2540C	Oven (Despatch Co.USA) (Standard methods for Analysis of water and wastewater, 20th Edition, APHA, AWWA, WEE, 1998)
TSS	Standard Method 2540C	Oven (Despatch Co.USA) (Standard methods for Analysis of water and wastewater, 20th Edition, APHA, AWWA, WEE, 1998)
TDS	Standard Method 2540C	Oven (Despatch Co.USA) (Standard methods for Analysis of water and wastewater, 20th Edition, APHA, AWWA, WEE, 1998)

3.5 Pollution Load Calculation:

BOD in kg/day= (1 mg/l)*(1 m^3/s)* (1000 l/1 m^3)*(1gm/1000 mg)*(1 kg/1000 gm)* (24*60*60 sec/ day)

Where, Concentration of BOD_5 in mg/l, Flow rate in m^3/s, 1 m^3= 1000 l, 1 gm= 1000 mg

1 kg= 1000 gm, 1 day= 24*60*60 sec

3.6 Standard Deviation calculation:

Standard Deviation calculation for the BOD concentration 11, 9, 9, 10, 11 mg/l

$$\Sigma x_i = 11+9+9+10+11=50$$

$$\Sigma x_i^2 = 121+81+81+100+121= 504$$

$$N=5$$

$$5\,\delta_x^2 = 504-(50)^2/5 = 504-500= 4$$

$$\delta_x^2 = 0.80$$

$$\delta_x = 0.89$$

Standard Deviation= 0.89

CHAPTER 4

CHARACTERIZATION OF EFFLUENT

4.1 Introduction

Effluent is liquid waste product (whether treated or untreated) discharged from an industrial process or human activity that is discharged into the environment. Another way, Effluent is a waste product, which could be in any of the three states of matter, discharged from boundary of manufacturers to the environment (Bridgewater and Mumfod, 1979). They are wastes resulting from processes employed in industrial establishments to the environment; they could be reused after recovery. Water, which has been described by many as the most essential commodity required for man's survival has received enormous environmental abuse. Process industries and sewage systems are particularly guilty of pollution of water systems (Asubiojo et al., 1993). The highest numbers of industrial establishments in the country are located in the North Central (NC) region, which comprises about 49 per cent of the total sector. About 33 per cent of the industries in the NC region are textiles, apparels and tanneries, of which Dhaka district accounts for almost half and Narayanganj about 32 per cent. About 65 per cent of the total chemicals, plastics and petroleum industries are also located in the NC region, and concentrated in and around Dhaka, Narayanganj and Gazipur districts (WARPO, 2000). The organic pollutants are both biodegradable and non-biodegradable in nature. The biodegradable organic components degrade water quality during decomposition by depleting dissolved oxygen. The non-biodegradable organic components persist in the water system for a long time and pass into the food chain (Ahmed and Reazuddin, 2000). Inorganic pollutants are mostly metallic salts, and basic and acidic compounds. These inorganic components undergo different chemical and biochemical interactions in the river system, and deteriorate waterquality.

The wastewater discharging from the fertilizer factories has different characteristics. It is of utmost importance to know the different parameters of this wastewater in order to assess and identify the water quality deterioration of the river and the design of the wastewater treatment plant.

4.2 Wastewater Quality Analysis

As the study area were fertilizer factories, the effluent parameters analyzed were pH, Biochemical Oxygen Demand (BOD_5), Chemical Oxygen Demand (COD), Dissolved Oxygen (DO), Total Ammonia (NH_3-N), Ammonia as nitrogen (NH_3-N), Ammonium as Nitrogen (NH_4-N), Temperatute, Total Solids (TS), Total Suspended Solids(TSS), Total Dissolved Solids(TDS).

The Detailed Chacterization of effluent from fertilizer factories are as follows
The values of effluent parameters shows in range and mean values (means ± Standard Deviation) are in parentheses.

4.2.1 Biochemical Oxygen Demand (BOD)

The level of BOD_5 of effluent from Polash and Ghorasal Urea Fertilizer Factories are shown in Figure 4.1 and Table A4.1. The levels of Biochemical Oxygen Demand (BOD_5) were 43-60 mg/l (50±5.76 mg/l) in the effluent from sampling point-2, 24-46 mg/l (32.20±8.08 mg/l) in the effluent from sampling point-3, 120-148 mg/l (135.20±9.83 mg/l) in the effluent from sampling point-4, 21-31 mg/l (28.20±3.66 mg/l) in the effluent from sampling point-5, 19-53 mg/l (36.80±11 mg/l) in the effluent from sampling point-7. According to the Bangladesh standard, BOD_5 should be within 50mg/l before discharging into inland water. BOD_5 were found lower than the effluent standard limit at the sampling point-2, 3, 5, and 7. But in the sampling point-4, BOD_5 were found higher than the standard limit. The samples in this drain were the combination of treated effluent discharged from the Polash urea fertilizer factory, treated effluent discharged from Lagoon and house hold waste discharged from the residendial area of fertilizer factories. Due to the household waste BOD_5 were high at this point. This drain discharged effluent into the Lakhya River. So BOD_5 is a concern of the effluent from sampling point-4 which is discharging into the Lakhya River.

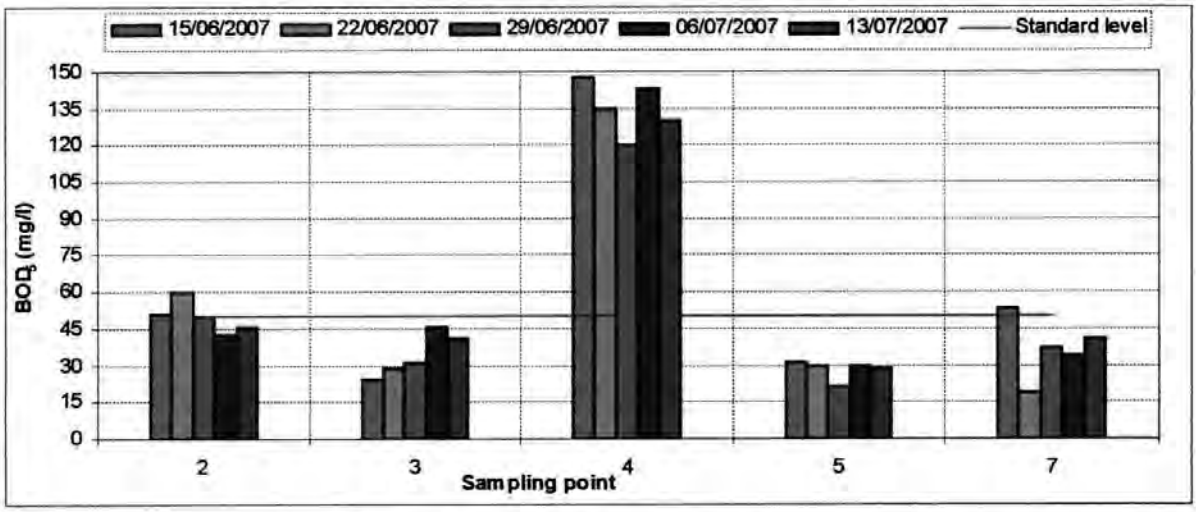


Figure 4.1: Variation of BOD_5 in mg/l at different sampling points of fertilizer factories

4.2.2 Chemical Oxygen Demand (COD)

The concentrations of COD of effluent from Polash and Ghorasal Urea Fertilizer Factories are shown in Figure 4.2 and Table A4.2. The levels of Chemical Oxygen Demand (BOD) were 78-86 mg/l (81.60±2.87mg/l) in the effluent from sampling point-2, 43-69 mg/l (55.20±9.89mg/l) in the effluent from sampling point-3, 198-234 mg/l (214.20±11.60 mg/l) in the effluent from sampling point-4, 37-53 mg/l (45.80±5.88 mg/l) in the effluent from sampling point-5, 52-64 mg/l (57.60±4.22 mg/l) in the effluent from sampling point-7. According to the Bangladesh standard, COD should be within 200 mg/l before discharging into inland water. COD were found within the effluent standard limit at the sampling point-2, 3, 5, and 7. But in the sampling point-4, COD were found higher than the standard limit. The samples in this drain were the combination of treated effluent discharged from the Polash urea fertilizer factory, treated effluent discharged from Lagoon and household waste discharged from the residensial area of fertilizer factories. Due to the omestic waste COD were high at this point. This drain discharged effluent into the Lakhya River. So COD is a concern of the effluent from sampling point-4 which is discharging into the Lakhya River.

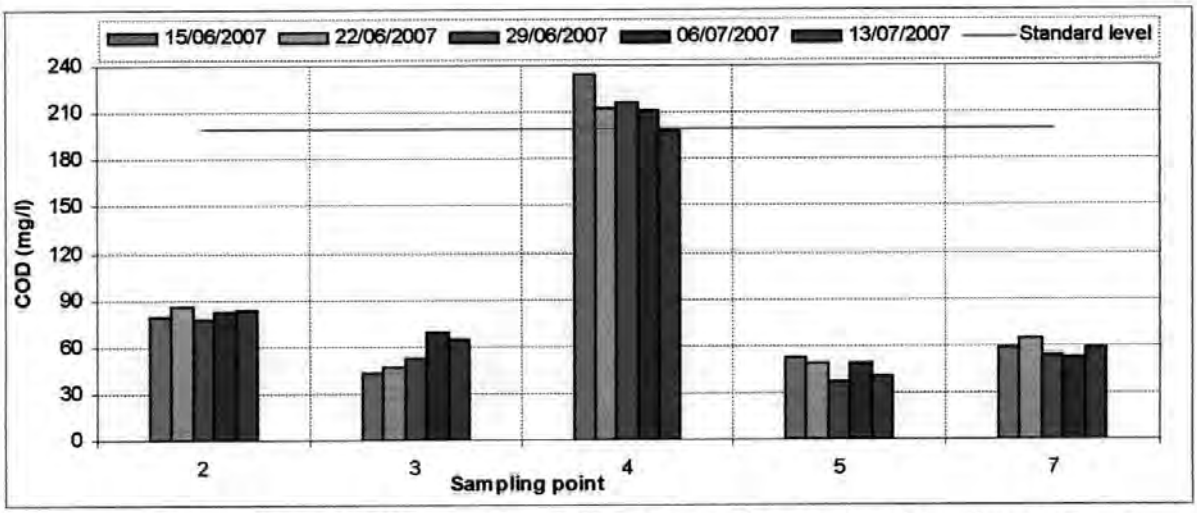


Figure 4.2: Variation of COD in mg/l at different sampling points of fertilizer factories

4.2.3 Dissolved Oxygen (DO)

The level of DO of effluent from Polash and Ghorasal Urea Fertilizer Factories are shown in Figure 4.3 and Table A4.3. The levels of Dissolved Oxygen (DO) were 0.65-0.78 mg/l (0.728±0.047mg/l) in the effluent from sampling point-2, 2.86-2.96 mg/l (2.898±0.037mg/l) in the effluent from sampling point-3, 2.81-2.91 mg/l (2.858±0.040mg/l) in the effluent from sampling point-4, 2.64-2.89 mg/l (2.734±0.085mg/l) in the effluent from sampling point-5, 2.8-3 mg/l (2.896±0.065mg/l) in the effluent from sampling point-7. According to the Bangladesh standard, DO should be 4.5-8 mg/l before discharging into inland water. DO were found below the effluent standard limit at the sampling point-2, 3, 4, 5 and 7. So these DO levels indicate the poor quality effluent discharge from the fertilizer factories.

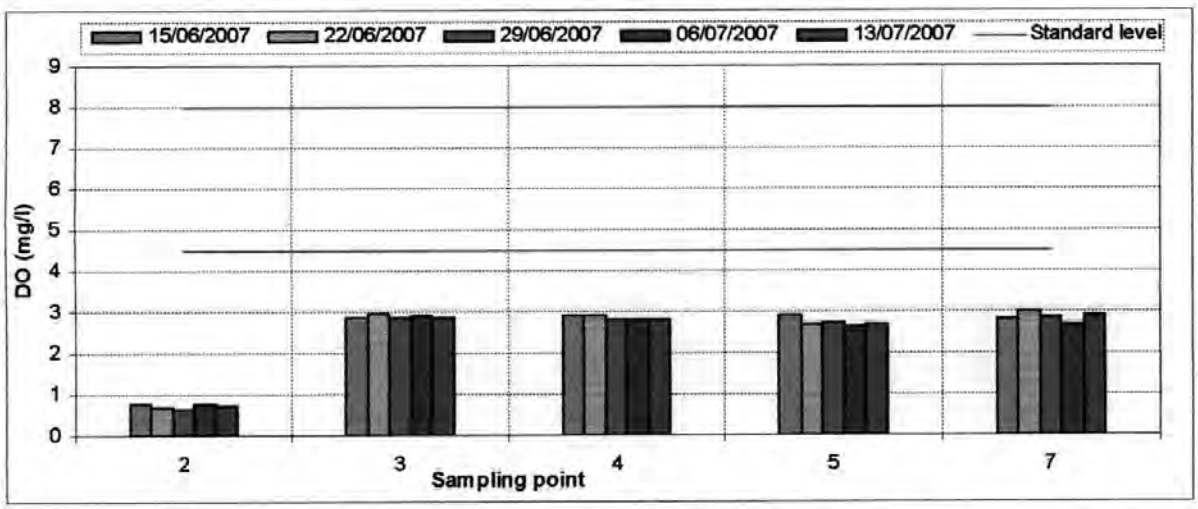


Figure 4.3: Variation of DO in mg/l at different sampling points of fertilizer factories

4.2.4 pH

The value of pH of effluent from Polash and Ghorasal Urea Fertilizer Factories are shown in Figue 4.4 and Table A4.4. The levels of pH were 8.4-8.9 mg/l (8.52±0.19mg/l) in the effluent from sampling point-2, 8.2-8.5 mg/l (8.34±0.10mg/l) in the effluent from sampling point-3, 8.8-9.3 mg/l (9.04±0.19mg/l) in the effluent from sampling point-4, 9.2-9.8 mg/l (9.58±0.21mg/l) in the effluent from sampling point-5, 8.2-8.8 mg/l (8.56±0.23mg/l) in the effluent from sampling point-7. In the sampling point-2, 3, 4, 5 and 7 the value of pH is greater than 7 which means the effluent quality is alkaline. According to the Bangladesh standard, pH should be 6-9 before discharging into inland water. pH were found below the effluent standard limit in the sampling point-2, 3, and 7. But the value of pH in the sampling point 4 and 5 is greater than the standard limit.

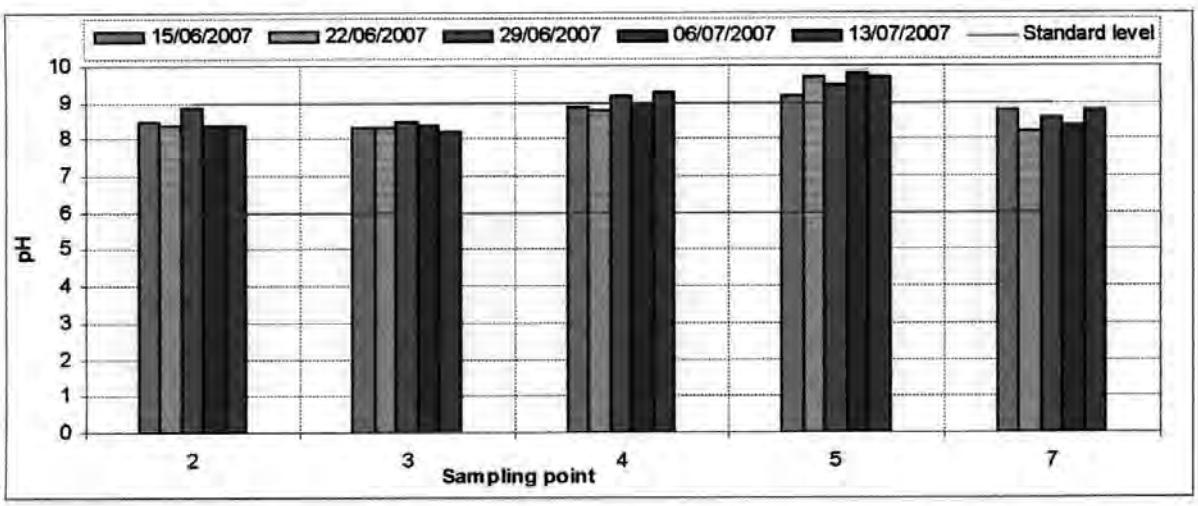


Figure 4.4: Variation of pH at different sampling points of fertilizer factories

4.2.5 Temperature

The value of Temperature of effluent from Polash and Ghorasal Urea Fertilizer Factories are shown in Figure 4.5 and Table A4.5. The value of Temperature were 30.4-31 °C (30.60±0.38°C) in the effluent from sampling point-2, 33-36 °C (34.32±0.98°C) in the effluent from sampling point-3, 31-34.7°C (32.64±1.21°C) in the effluent from sampling point-4, 42-46.5°C (45.20±1.69°C) in the effluent from sampling point-5, 38-38.6°C (38.20±0.25°C) in the effluent from sampling point-7. According to the Bangladesh standard, Temperature should be within 40°C (summer) or 45°C (winter) before discharging into inland water. Temperature was found near or within the effluent standard limit in the sampling point-2, 3, 4, and 7. But

in the sampling point-5, Temperature was found higher than the standard limit. The effluent discharging directly into the river from this point is untreated and held maximum temperature. So Temperature is a concern of the effluent from sampling point-5 which is discharging into the Lakhya River

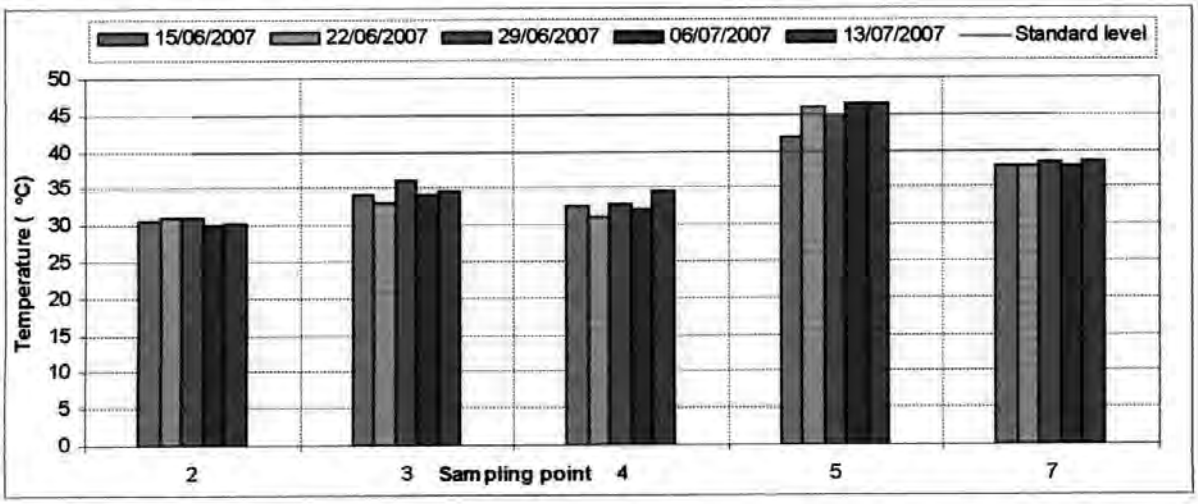


Figure 4.5: Variation of Temperature in °C at different sampling points of fertilizer factories

4.2.6 Total Ammonia (NH_3-N+ NH_4-N)

The concentration of Total Ammonia of effluent from Polash and Ghorasal Urea Fertilizer Factories are shown in Figure 4.6 and Table A4.6. The concentrations of Total Ammonia were 685-697.5 mg/l (691.90±4.29mg/l) in the effluent from sampling point-2, 85-120 mg/l (104.40±13.29mg/l) in the effluent from sampling point-3, 434-460 mg/l (444.40±9.41mg/l) in the effluent from sampling point-4, 997.5-1230 mg/l (1098.50±79.27mg/l) in the effluent from sampling point-5, 95-147 mg/l (125.70±16.99mg/l) in the effluent from sampling point-7. According to the Bangladesh standard, Total Ammonia should be within 50 mg/l before discharging into inland water. Total Ammonia was found higher than the effluent standard limit in the sampling point-2, 3, 4, 5, and 7. Treated effluent of Polash and Ghorasal Urea Fertilizer Factories were discharged by the sampling point-3 and 7 respectively. But the concentration of Total Ammonia is very high than the standard limit. So it can be mentioned that proper effluent treatment process were not maintained. On the other hand untreated effluent discharged into the lagoon in one side and it discharged by the other side into the Lakhya River. For this, retension period is less than required, hence high values of ammonia were found. In the sampling point-4, household effluent were added hence the total amount of Ammonia were higher than the amount discharged from sampling point-2 and 3. Untreated

effluent was discharged directly into the Lakhya River from sampling point-5. Discharging effluent this point contains high concentration of Ammonia which was very much vulnerable to the environment. So Total Ammonia is a serious concern of the effluent from all sampling point which is discharging into the Lakhya River.

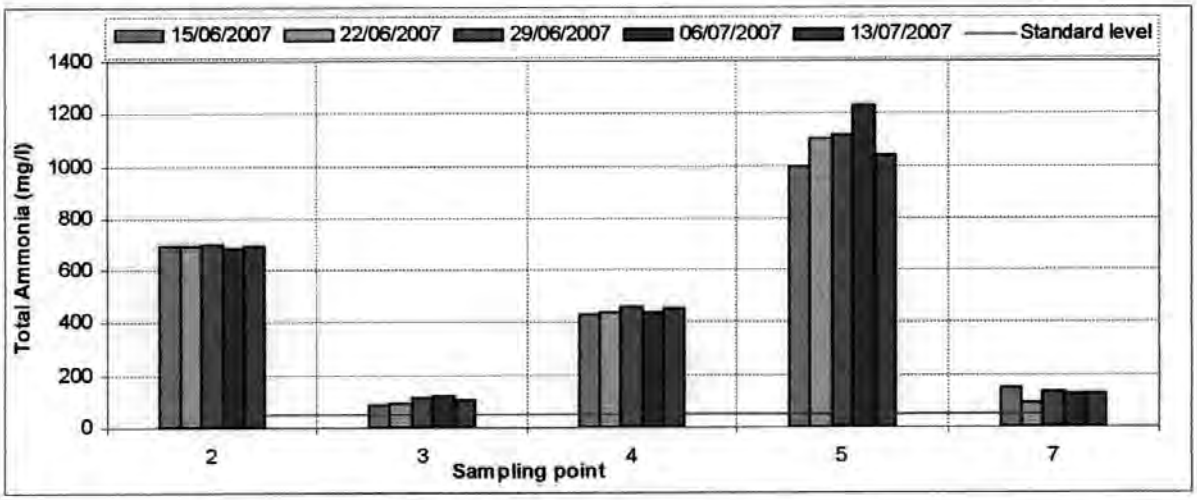


Figure 4.6: Variation of Total Ammonia at different sampling points of fertilizer factories

4.2.7 Ammonia as Nitrogen (NH_3-N)

The concentration of NH_3-N (Ammonia as Nitrogen) of effluent from Polash and Ghorasal Urea Fertilizer Factories are shown in Figure 4.7 and Table A4.7. The concentrations of Ammonia as Nitrogen (NH_3-N) were 83.09-211.95 mg/l (113.09±49.94mg/l) in the effluent from sampling point-2, 8.4-17.03 mg/l (11.58±3.54mg/l) in the effluent from sampling point-3, 112.77-235.35 mg/l (170.03±47.20 mg/l) in the effluent from sampling point-4, 464.35-954.67 mg/l (740.72±260.27mg/l) in the effluent from sampling point-5, 7.61-37.85 mg/l (23.53±11.19 mg/l) in the effluent from sampling point-7. According to the Bangladesh standard, NH_3-N should be within 5 mg/l before discharging into inland water. NH_3-N (Ammonia as Nitrogen) was found higher than the effluent standard limit in the sampling point-2, 3, 4, 5, and 7. Treated effluent of Polash and Ghorasal Urea Fertilizer Factories were discharged by the sampling point-3 and 7 respectively. But the concentration of Ammonia (NH_3-N) is very high than the standard limit. So it can be mentioned that proper effluent treatment process were not maintained. So NH_3-N (Ammonia as Nitrogen) is a serious concern of the effluent from all sampling point that is discharging into the Lakhya River.

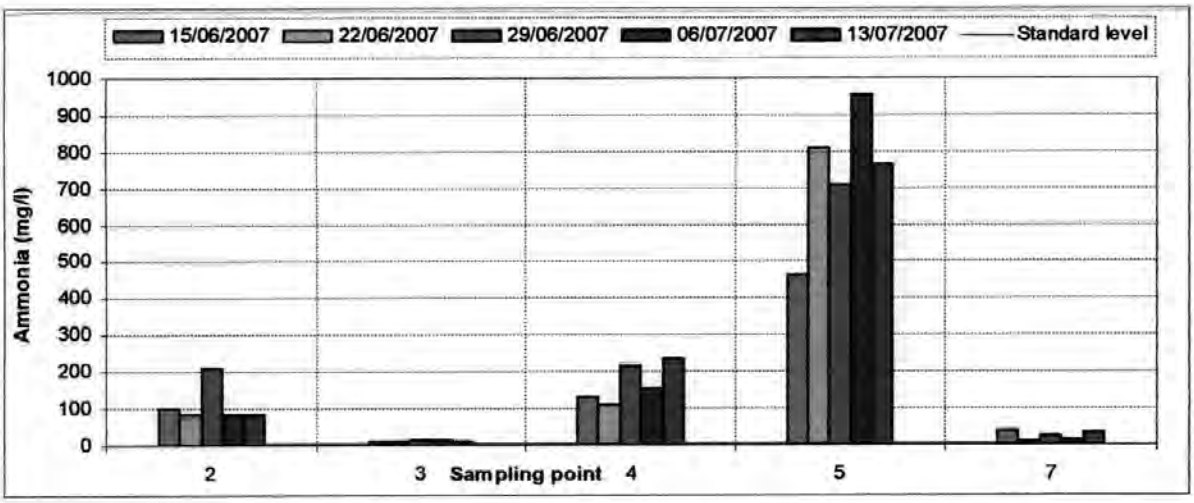


Figure 4.7: Variation of NH_3-N in mg/l at different sampling points of fertilizer factories

4.2.8 Ammonium as Nitrogen (NH_4-N)

The concentration of NH_4-N (Ammonium as Nitrogen) of effluent from Polash and Ghorasal Urea Fertilizer Factories are shown in Figure 4.8 and Table A4.8. The concentrations of Ammonium as Nitrogen (NH_4-N) were 485.55-610.7 mg/l (578.81±47.30 mg/l) in the effluent from sampling point-2, 76.6-105.44 mg/l (92.82±10.82 mg/l) in the effluent from sampling point-3, 214.65-325.23 mg/l (274.36±39.56 mg/l) in the effluent from sampling point-4, 275.33-533.14 mg/l (357.78±100.72 mg/l) in the effluent from sampling point-5, 87.39-110.28 mg/l (102.16±8.86 mg/l) in the effluent from sampling point-7. According to the Bangladesh standard, NH_4-N should be within 50 mg/l before discharging into inland water. NH_4-N was found higher than the effluent standard limit in the sampling point-2, 3, 4, 5, and 7. Treated effluent of Polash and Ghorasal Urea Fertilizer Factories were discharged by the sampling point-3 and 7 respectively. But the concentration of NH_4-N is very high than the standard limit. So it can be mentioned that proper effluent treatment process were not maintained. So NH_4-N (Ammonium as Nitrogen) is a serious concern of the effluent from all sampling point which is discharging into the Lakhya River.

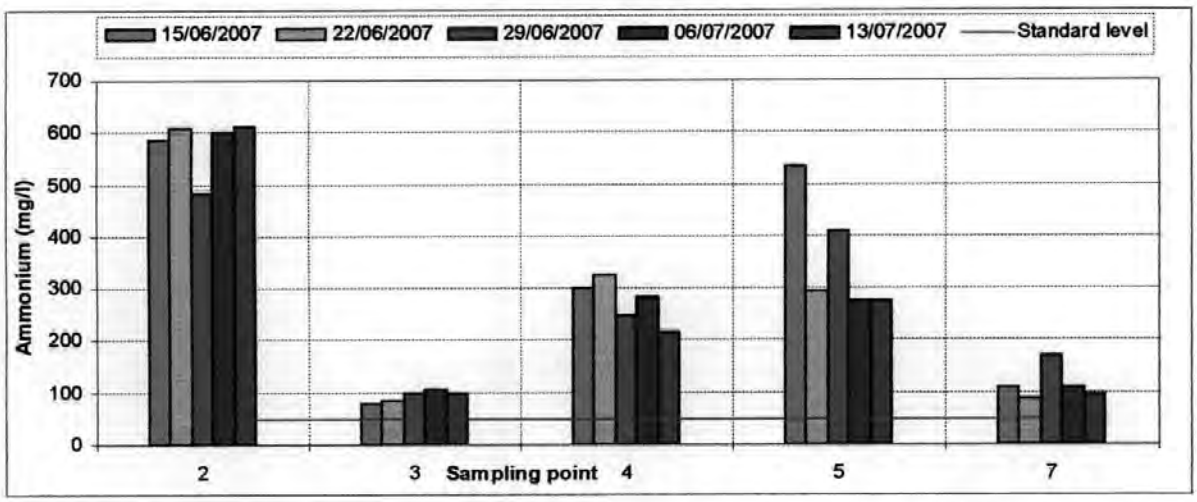


Figure 4.8: Variation of NH_4-N in mg/l at different sampling points of fertilizer factories

4.2.9 Total Solids (TS)

The concentrations of Total Solids (TS) of effluent from Polash and Ghorasal Urea Fertilizer Factories are shown in Figure 4.9 and Table A4.9. The concentrations of Total Solids (TS) were 112-183 mg/l (147±26.13mg/l) in the effluent from sampling point-2, 45-90 mg/l (69.20±14.54mg/l) in the effluent from sampling point-3, 154-247 mg/l (210.40±45.47mg/l) in the effluent from sampling point-4, 215-274 mg/l (236.60±21.23mg/l) in the effluent from sampling point-5, 389-459 mg/l (448±47.57mg/l) in the effluent from sampling point-7. According to the Bangladesh standard, TS should be within 2100 mg/l before discharging into inland water. TS were found lower than the effluent standard limit in the sampling point-2, 3, 4, 5 and 7. So the concentration of TS is not a concern of the effluent which is discharging into the Lakhya River.

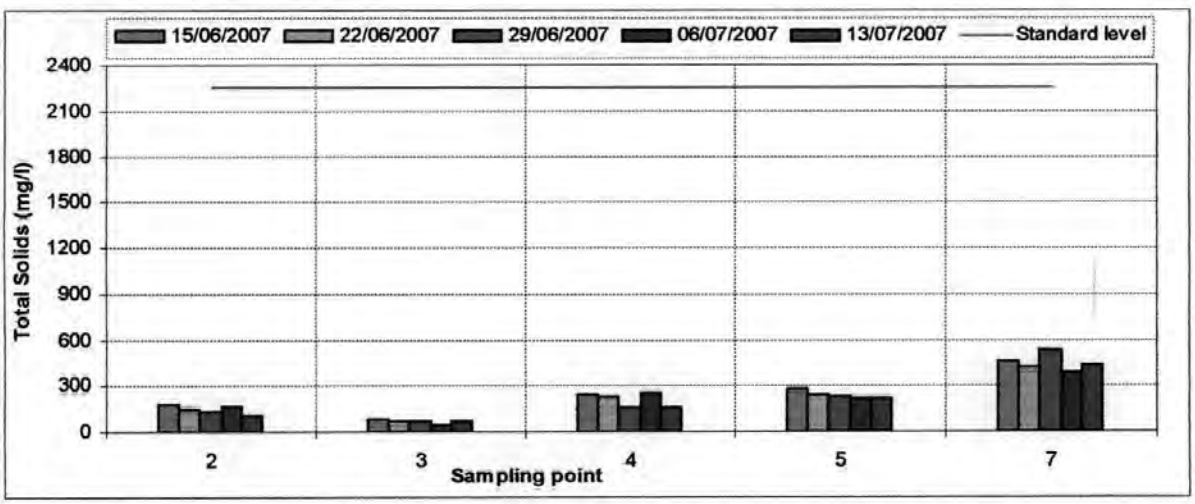


Figure 4.9: Variation of Total Solids at different sampling points of fertilizer factories

4.2.10 Total Suspended Solids (TSS)

The concentrations of Total Suspended Solids (TSS) of effluent from Polash and Ghorasal Urea Fertilizer Factories are shown in Figure 4.10 and Table A4.10. The concentrations of Total Suspended Solids (TSS) were 27-47 mg/l (38±6.99mg/l) in the effluent from sampling point-2, 13-23 mg/l (18.20±3.71 mg/l) in the effluent from sampling point-3, 30-84 mg/l (60.40±20.50 mg/l) in the effluent from sampling point-4, 17-67 mg/l (41.20±16mg/l) in the effluent from sampling point-5, 129-179 mg/l (147±18.43mg/l) in the effluent from sampling point-7. According to the Bangladesh standard, TSS should be within 150 mg/l before discharging into inland water. TSS was found lower than the effluent standard limit in the sampling point-2, 3, 4, 5 and 7. So the concentration of TSS is not a concern of the effluent which is discharging into the Lakhya River.

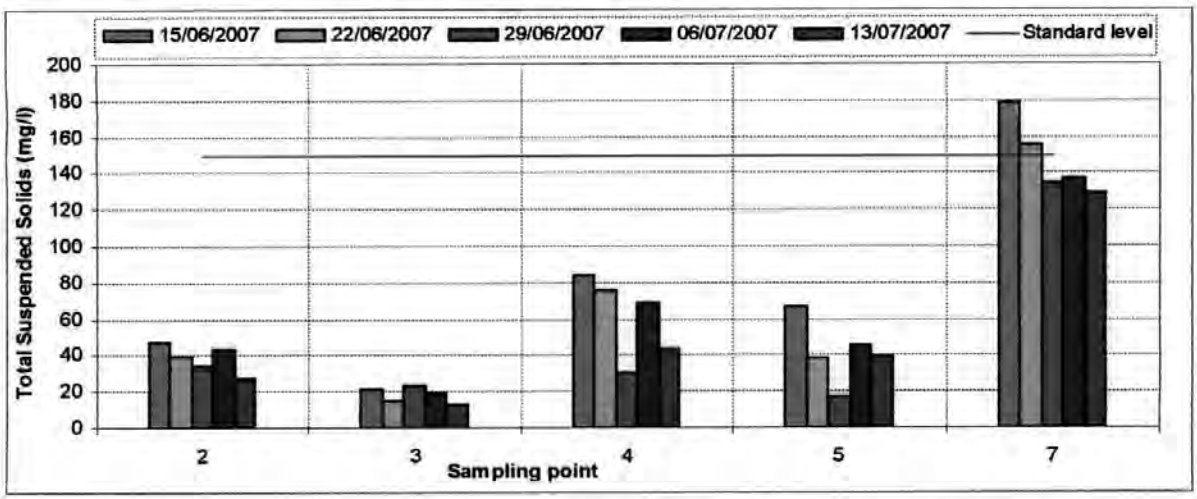


Figure 4.10: Variation of TSS in mg/l at different sampling points of fertilizer factories

4.2.11 Total Dissolved Solids (TDS)

The concentrations of Total Dissolved Solids (TDS) of effluent from Polash and Ghorasal Urea Fertilizer Factories are shown in Figure 4.11 and Table A4.11. The concentrations of Total Dissoved Solids (TDS) were 85-136 mg/l (109±19.29mg/l) in the effluent from sampling point-2, 26-69 mg/l (51±14.86mg/l) in the effluent from sampling point-3, 111-190 mg/l (149±28.81mg/l) in the effluent from sampling point-4, 176-211 mg/l (195.40±15.91mg/l) in the effluent from sampling point-5, 252-303 mg/l (301±51.18mg/l) in the effluent from sampling point-7. According to the Bangladesh standard, TDS should be

within 2100 mg/l before discharging into inland water. TDS was found below the effluent standard limit in the sampling point-2, 3, 4, 5 and 7. So the concentration of TDS is not a concern of the effluent discharging into the Lakhya River.

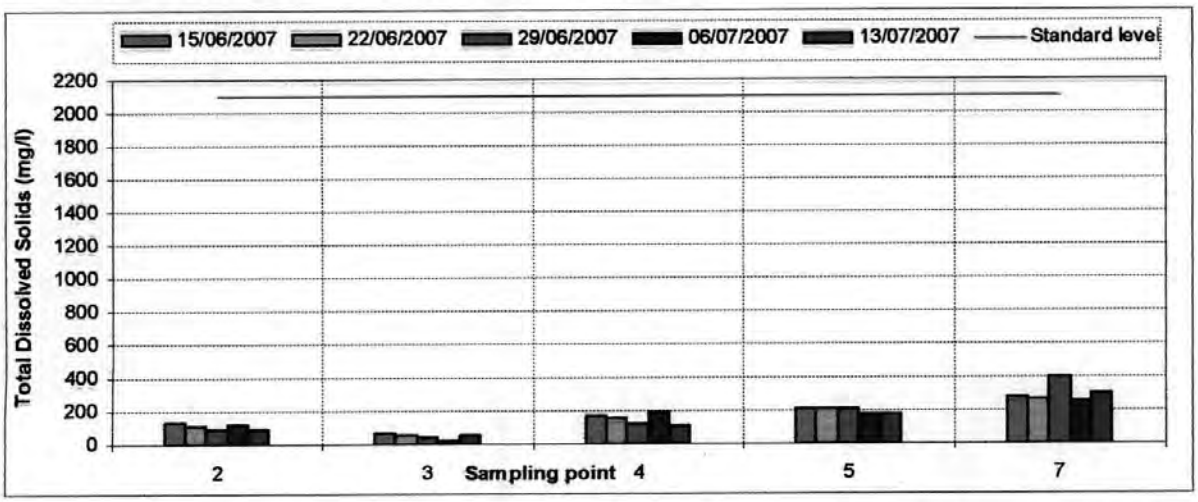


Figure 4.11: Variation of TDS in mg/l at different sampling points of fertilizer factories

CHAPTER 5

ESTIMATION OF WATER POLLUTION LOAD

5.1 Introduction

Unplaned growth of industries and lack of treatment facilities of industrial waste water is the primary cause of water pollution in Bangladesh. Water pollution disturbs the normal uses of water for irrigation, agriculture, industry, public water supply and aquatic life. Prevention of water pollution is not only important from the viewpoint of public health, but also from the viewpoint of aesthetics, conservation and preservation of natural resources. In Bangladesh, pollution of surface water bodies from industrial effluents is a major concern. Here majority of the industrial wastes is discharged into surface water bodies without any kind of treatment. According to the study (BKH, 1995), an estimated 32 million kilogram of BOD are discharged into the environment annually, most of which end up in the surface water bodies around the industrial locations. While this figure is quite alarming it must be recognized that the number of industrial units and industrial production have increased significantly since these estimates were made; and the present estimates of wastewater flow and waste load are expected to be significantly higher.

5.2 Estimation of Effluent flow rate Discharged from Fertilizer Factories

The measurements of effluent flow rate from sampling point-2, 3, 4, 5 and 7 were 0.125-0.15 m^3/s (0.137±0.009), 0.0262-0.0266 m^3/s (0.026±0.000), 0.211-0.249 m^3/s (0.023±0.013), 0.08-0.13 m^3/s (0.092±0.019) and 0.065-0.071 m^3/s (0.068±0.003) respectively. The flow measurement are shown in Figure 5.1 and Table A5.1

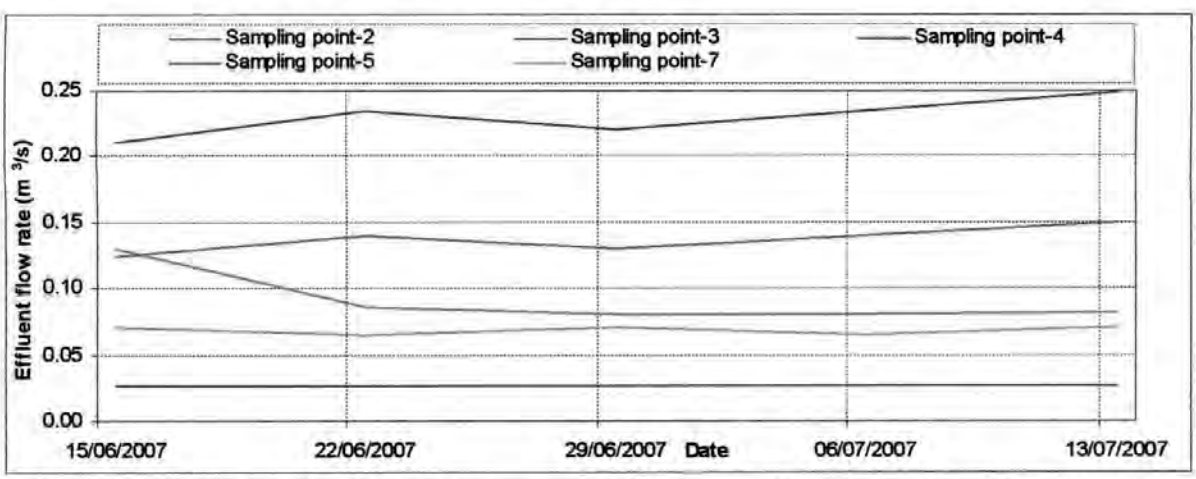


Figure 5.1 Variation of effluent flow rate at different sampling point of fertilizer factories

5.3 Estimation of Water Pollution Load Discharged from Different Sampling Points of Fertilizer Factories

5.3.1 Sampling point-4

Two kinds of effluents were discharged from this point. One is industrial effluent comes from Polash and Ghorasal Urea Fertilizer factories and another is domestic effluent comes from residential area. Pollution load (Industrial and Residential) were discharged from sampling point-4 are shown in Table A5.2 and A5.3. The amount of pollution load discharged from sampling point-4 into the Lakhya River were, Biochemical Oxygen Demand (BOD_5) were 2291-2903 kg/day (2683±208.48 kg/day) where as 1659.55-2277.62kg/day (2014.7±207.7 kg/day) discharged from residential area, Chemical Oxygen Demand (COD) were 4124-4286 kg/day (4244±60.69 kg/day) (Figure-5.2) where as 3036.93-3315 kg/day (3150±90 kg/day) discharged from residential area, Total Ammonia were 7911-9681 kg/day (8833±562.25 kg/day) where as 266.85-688.78 kg/day (404±154 kg/day) discharged from residential area, Ammonia as Nitrogen (NH_3-N) were 2279.94-5063.22 kg/day (3400.89±1052.68 kg/day), Ammonium as Nitrogen (NH_4-N) were 4617.89-6575.37 kg/day (5432.21±725.38 kg/day) (Figure-5.3), Total Solids (TS) were 2997-5258 kg/day (4164±865 kg/day) where as 1408.46-3099 kg/day (2271±642 kg/day) discharged from residential area, Total Suspended Solids (TSS) were 572-1536 kg/day (1193±382.65 kg/day) where as 545.29-1030.45 kg/day (705±329 kg/day) discharged from residential area, Total Dissolved Solids (TDS) were 2329-3857 kg/day (2952±564 kg/day) (Figure-5.4) where as 1174.11-2261.81 kg/day (1546±425 kg/day) discharged from residential area. The pollution load discharged from residential area into the sampling point-4 are shown in Figure 5.5

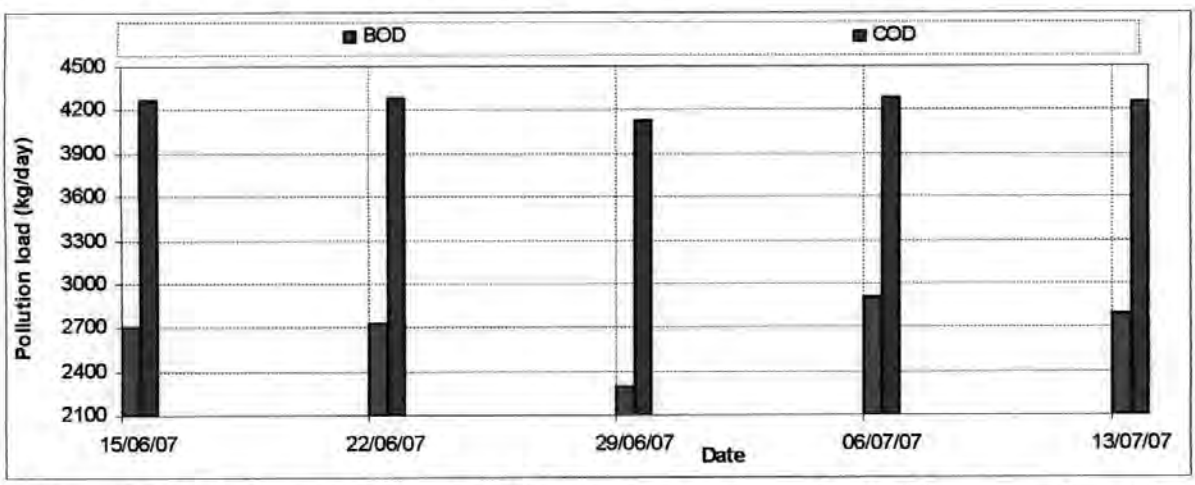


Figure 5.2 Variation of BOD_5 and COD in kg/day discharged load of from sampling point-4 into the Lakhya River

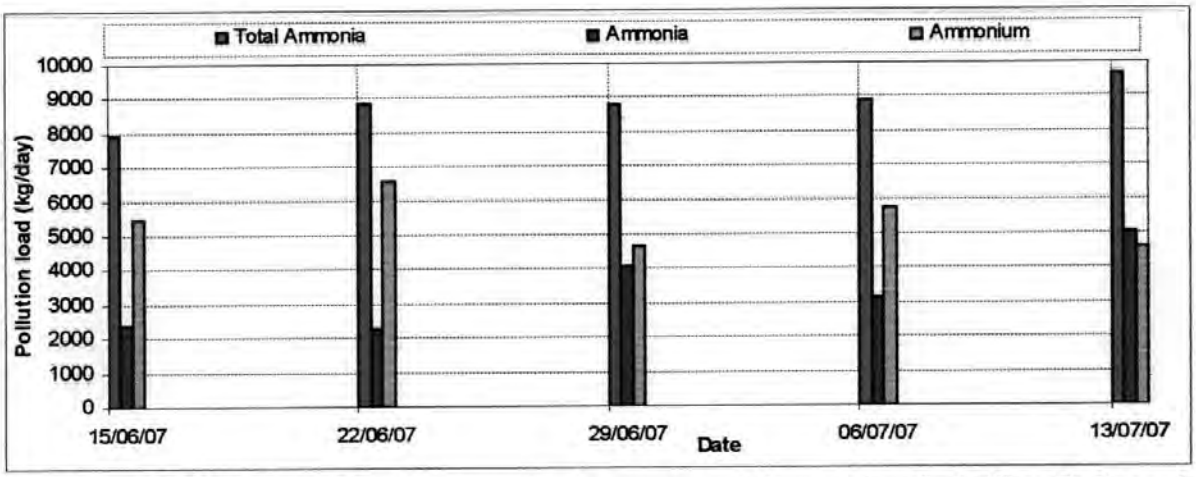


Figure 5.3 Variation of Total Ammonia, Ammonia and Ammonium in kg/day discharged from sampling point-4 into the Lakhya River

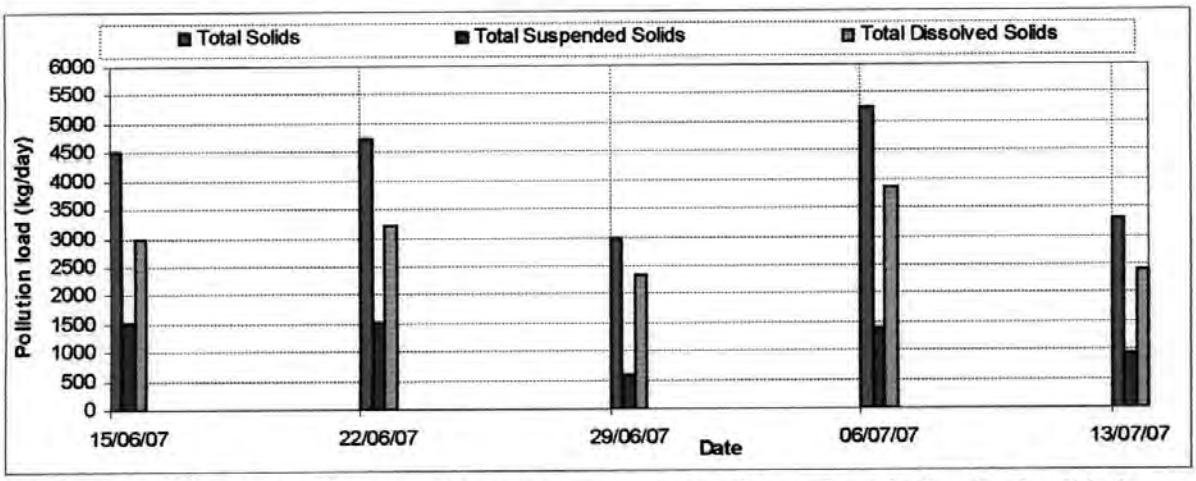


Figure 5.4 Variation of total solids, total suspended solids and total dissolved solids in kg/day discharged from sampling point-4 into the Lakhya River

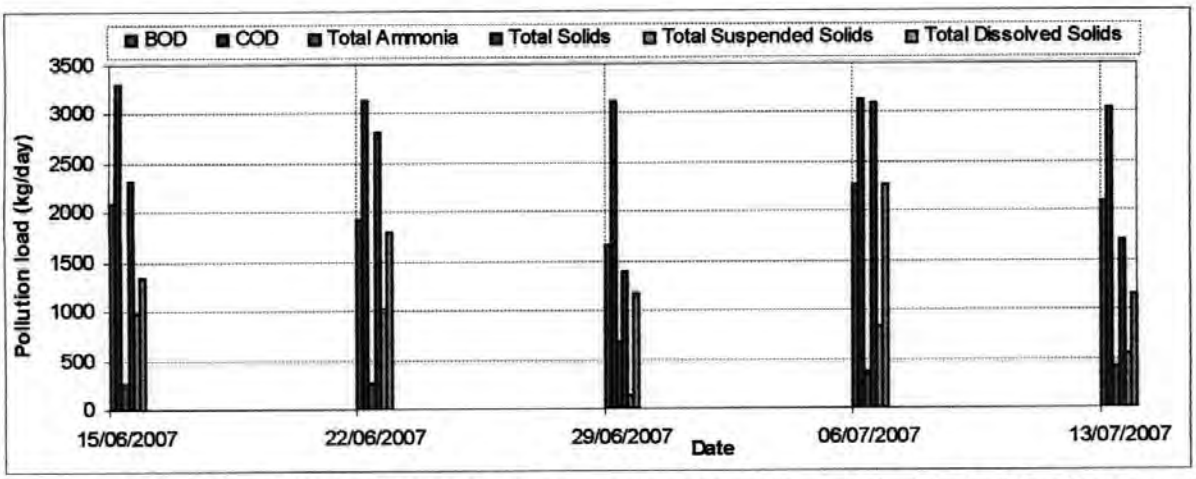


Figure 5.4 Variation of BOD, COD, Total Ammonia, TS, TSS, and TDS in kg/day discharged from residential area of fertilizer factories into the sampling point-4

5.3.2 Sampling point-5

Untreated effluent from Ghorasal Urea fertilizer factory was discharged through this point. Pollution load were discharged from sampling point-5 are shown in Table A5.4. The amount of pollution load discharged from sampling point-5 into the Lakhya River were Biochemical Oxygen Demand (BOD_5) were 146-348 kg/day (226±66.26 kg/day), Chemical Oxygen Demand (COD) were 258-595 kg/day (369±118.68 kg/day) (Figure-5.6) , Total Ammonia (NH_3-N) were 7368-11203 kg/day (8624±1344.34 kg/day), Ammonia as Nitrogen (NH_3-N) were 4975.23-6598.68 kg/day (5643.73±590.45 kg/day), Ammonium as Nitrogen (NH_4-N) were 1903.08-5988.22 kg/day (2980.78±1541.86 kg/day) (Figure-5.7), Total Solids (TS) were 1523-3077 kg/day (1908.88±594.29 kg/day), Total Suspended Solids (TSS) were 118-752 kg/day (348±213.03 kg/day), Total Dissolved Solids (TDS) were 1216-2325 kg/day (1560±402 kg/day) (Figure-5.8)

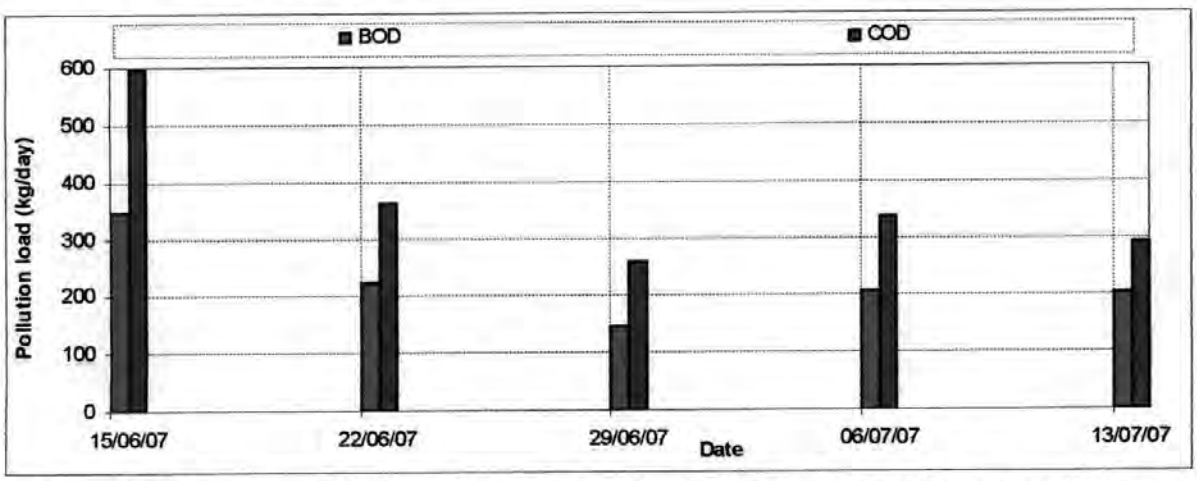


Figure 5.6 Variation of BOD_5 and COD in kg/day discharged load of from sampling point-5 into the Lakhya River

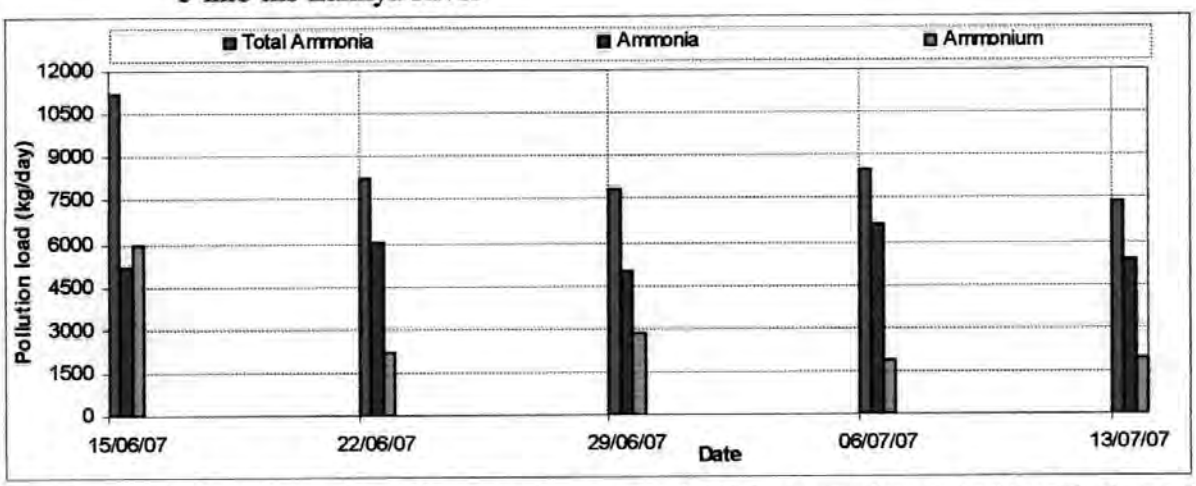


Figure 5.8 Variation of Total Ammonia, Ammonia and Ammonium in kg/day discharged from sampling point-5 into the Lakhya River

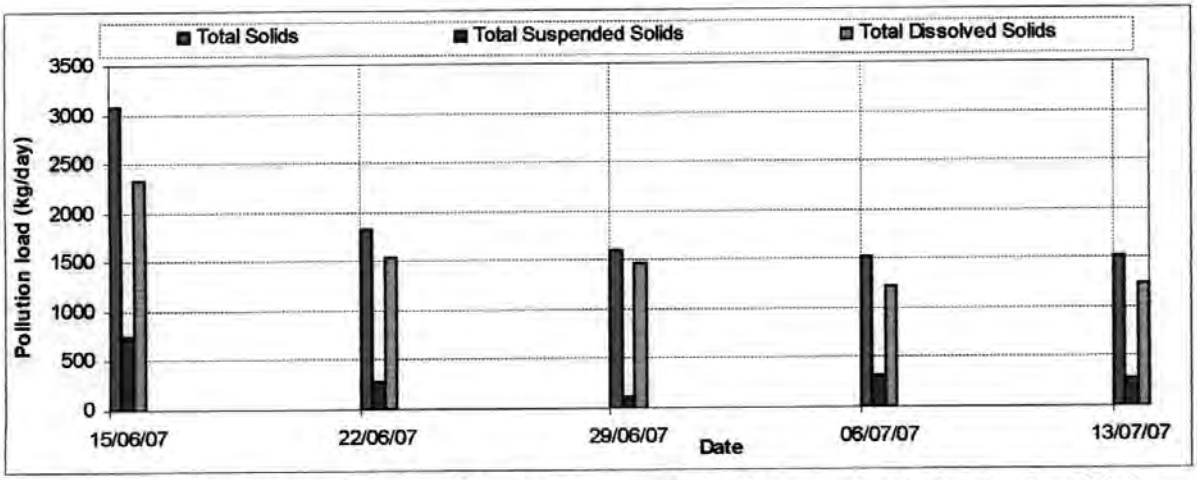


Figure 5.8 Variation of total solids, total suspended solids and total dissolved solids in kg/day discharged from sampling point-5 into the Lakhya River

5.3.3 Sampling point-7

Treated effluent from Ghorasal Urea fertilizer factory was discharged through this point. Pollution load were discharged from sampling point-7 are shown in Table A5.5. The amount of pollution load discharged from sampling point-7 into the Lakhya River were, Biochemical Oxygen Demand (BOD_5) were 106-323 kg/day (219±71 kg/day), Chemical Oxygen Demand (COD) were 292-359 kg/day (339±26 kg/day) (Figure-5.9), Total Ammonia (NH_3-N) were 531-896 kg/day (744±122 kg/day), Ammonia as Nitrogen (NH_3-N) were 42.60-230.88 kg/day (141.13±70.18 kg/day), Ammonium as Nitrogen (NH_4-N) were 489.27-665.79 kg/day (603.50±64.31 kg/day) (Figure-5.10), Total Solids (TS) were 2184-3263 kg/day (2651±369 kg/day), Total Suspended Solids (TSS) were 769-1091 kg/day (867±118 kg/day), Total Dissolved Solids (TDS) were 1415-2441 kg/day (1784±359 kg/day) (Figure-5.11)

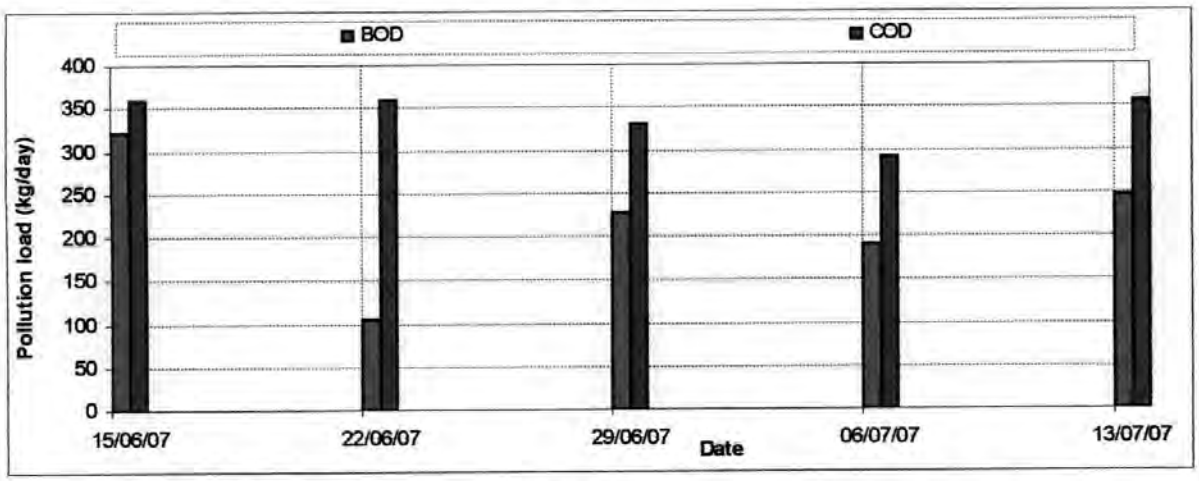


Figure 5.9 Variation of BOD_5 and COD in kg/day discharged load of from sampling point-5 into the Lakhya River

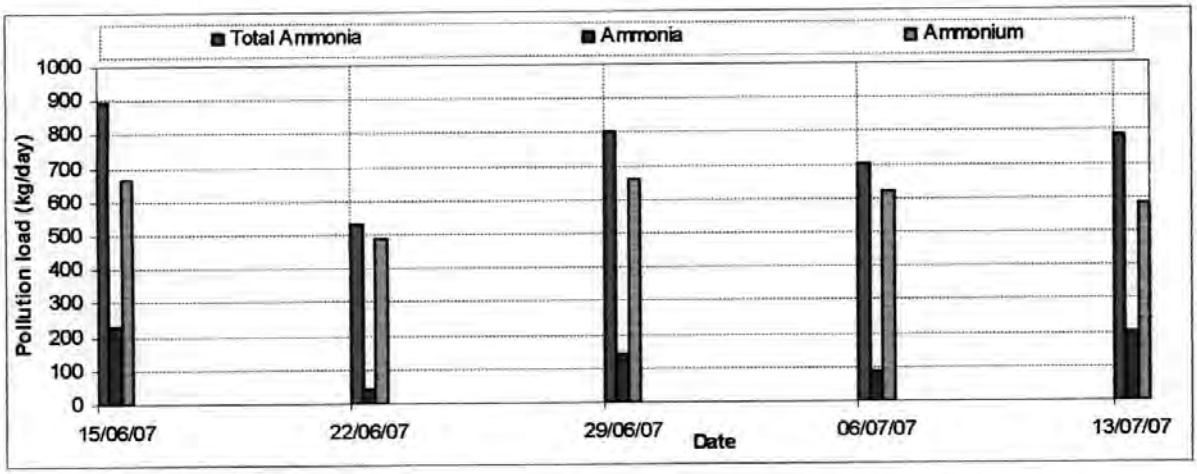


Figure 5.10 Variation of Total Ammonia, Ammonia and Ammonium in kg/day discharged from sampling point-5 into the Lakhya River

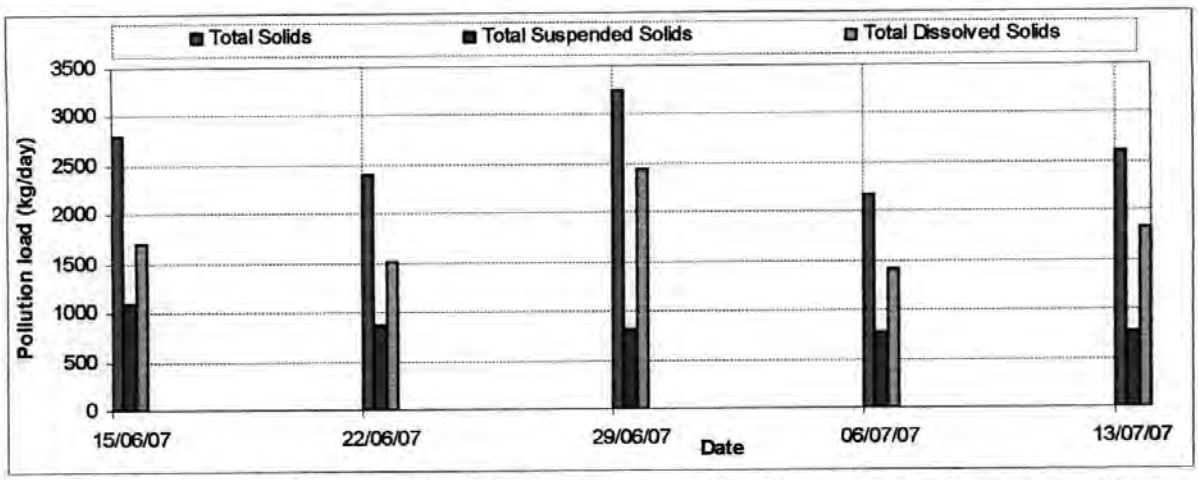


Figure 5.11 Variation of total solids, total suspended solids and total dissolved solids in kg/day discharged from sampling point-5 into the Lakhya River

5.4 Estimation of Total Water Pollution Load Discharged from Fertilizer Factories

Effluent from Polash and Ghorasal Urea fertilizer factories were discharged through the point of 4, 5, 7. Total water pollution load were discharged from fertilizer factories are shown in Table A5.6. The amount of pollution load discharged from fertilizer factories into the Lakhya River were, Biochemical Oxygen Demand (BOD_5) were 2665-3369 kg/day (3129±253kg/day), Chemical Oxygen Demand (COD) were 4714-5221 kg/day (4953±164kg/day) (Figure-5.12), Total Ammonia (NH_3-N) were 17425-20012 kg/day (18202±936 kg/day), Ammonia as Nitrogen (NH_3-N) were 7850.68-10671.21 kg/day (9185.76±1013.79 kg/day), Ammonium as Nitrogen (NH_4-N) were 7164.34-12161.79 kg/day (9016.51±1705.80 kg/day) (Figure-5.13), Total Solids (TS) were 7449-10380 kg/day (8725±1023kg/day), Total Suspended Solids (TSS) were 1513-3375 kg/day

(2408±633kg/day), Total Dissolved Solids (TDS) were 5467-7004 kg/day (6296±495kg/day) (Figure-5.14)

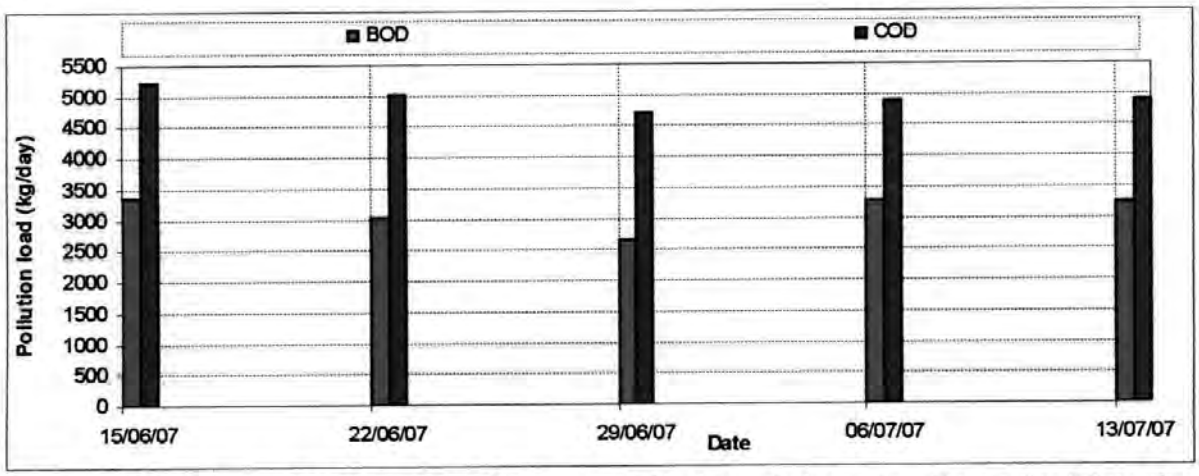


Figure 5.2 Variation of BOD_5 and COD in kg/day discharged from sampling point-5 into the Lakhya Rive

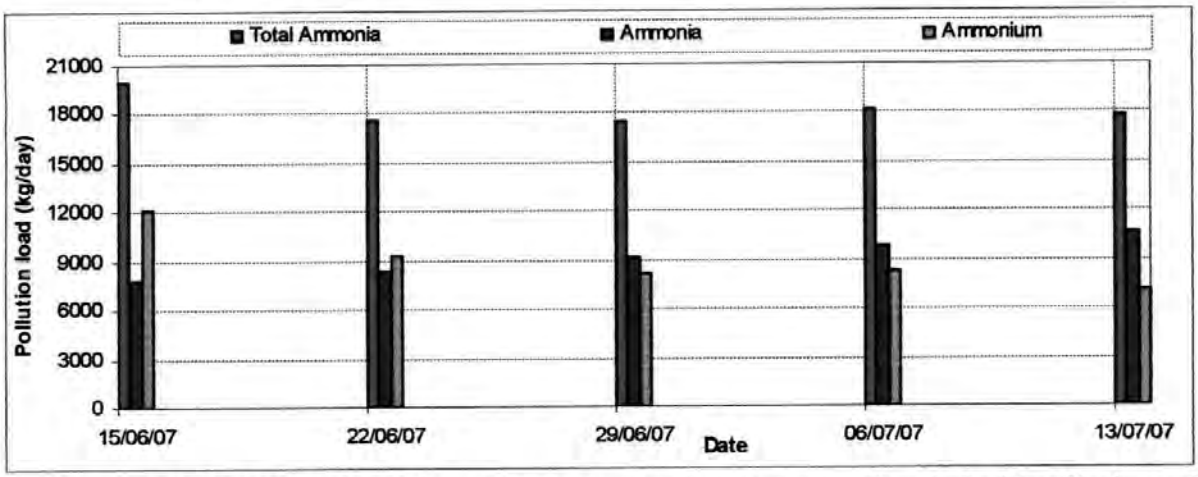


Figure 5.8 Variation of Total Ammonia, Ammonia and Ammonium in kg/day discharged from sampling point-5 into the Lakhya River

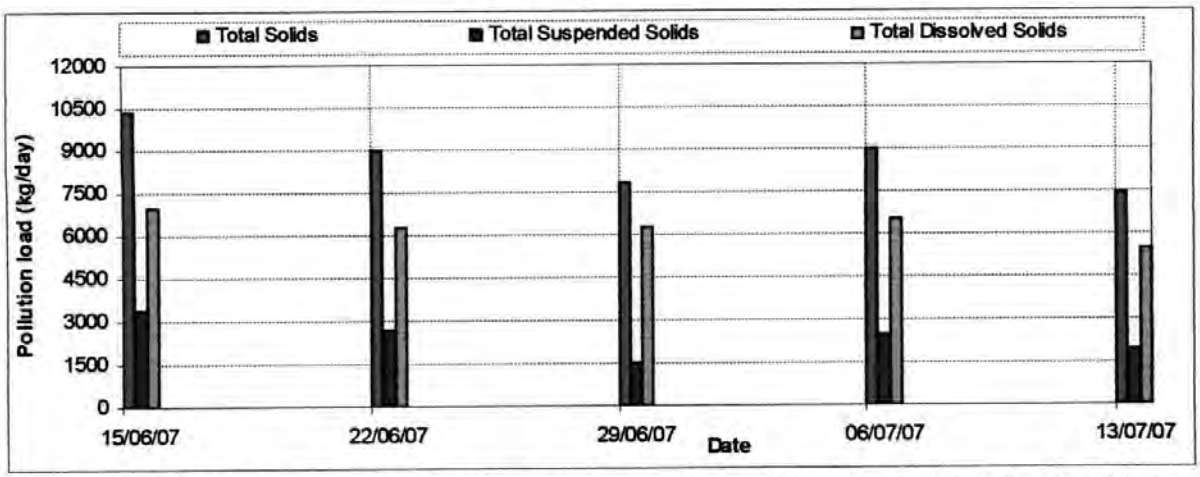


Figure 5.8 Variation of total solids, total suspended solids and total dissolved solids in kg/day discharged from sampling point-5 into the Lakhya River

CHAPTER 6

IMPACT OF EFFLUENT ON THE LAKHYA RIVER WATER QUALITY

6.1 Introduction

Rapid growth of industry in Bangladesh is putting stress on natural resources and the environment. Water and air pollution, degradation of land resources, soil erosion, over exploitation of land resources and threats to the ecosystem are among the most challenges. Besides mismanagement, important reasons for the rapid increase of environmental pollution are the limitations in the level of technology applied in industrial production process and wastes treatment (Hung, 1997).

Industrial production activities have impacts on the natural environment through the entire cycle of raw materials exploration and extraction, transformation into products, and use and disposal of products by the final consumers. All these activities generate wastes. Neither enterprises nor consumers want to store wastes in their own yards. Therefore, they have to find places and methods to get rid of it and frequently the natural environment is serving as the recipient of all kinds of wastes, among which industrial wastes with high toxicity and loading of contaminants. This study explains why industrial wastes are one of the major causes of severe causes of water pollution in Bangladesh.

6.2 Analysis of flow rate in the different points along the Lakhya River

6.2.1 Sampling point-1

The flow rate from sampling point-1 of Lakhya River is shown in Table A6.1. Flow rate (Figure-6.1) from sampling point-1 were 581.732-1032.429 m^3/s (824.86±155)

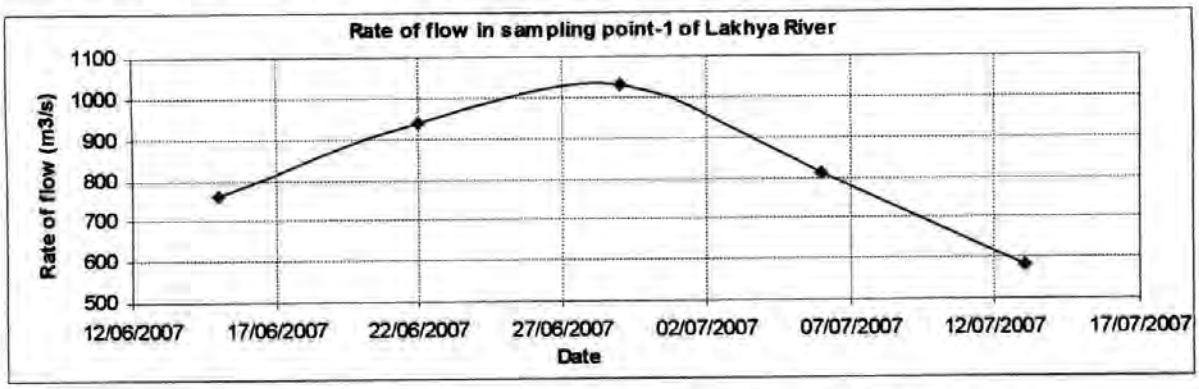


Figure 6.1 Variation of flow rate at sampling point-1 along the Lakhya River

6.2.2 Sampling point-6

The flow rate from sampling point-6 of Lakhya River is shown in Table A6.1. Flow rate (Figure-6.2) from sampling point-6 were 582.499-1033.324 m^3/s (825.6136±155)

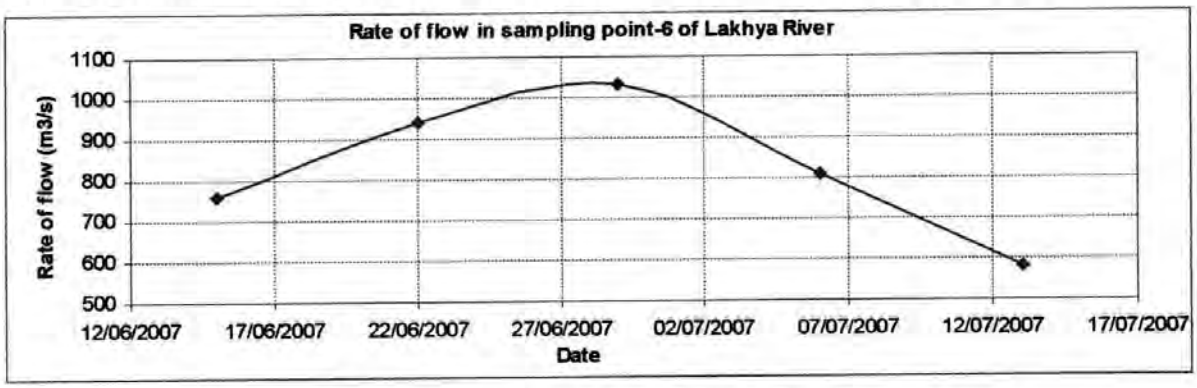


Figure 6.2 Variation of flow rate at the sampling point-6 along the Lakhya River

6.2.3 Sampling point-8

The flow rate from sampling point-8 of Lakhya River is shown in Table A6.1. Flow rate (Figure-6.3) from sampling point-8 were 582.882-1033.772 m^3/s (825.9916±155)

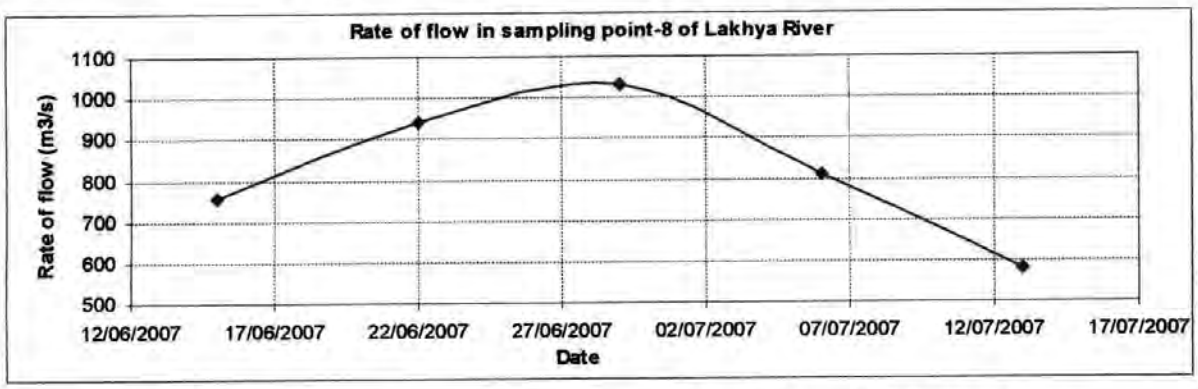


Figure 6.3 Variation of flow rate at the sampling point-8 along the Lakhya River

6.2.4 Sampling point-9

The measurements of flow rate from sampling point-9 of Lakhya River are shown in Table A6.1. Flow rate (Figure-6.4) from sampling point-9 were 583.266-1034.22 m^3/s (826.37±155)

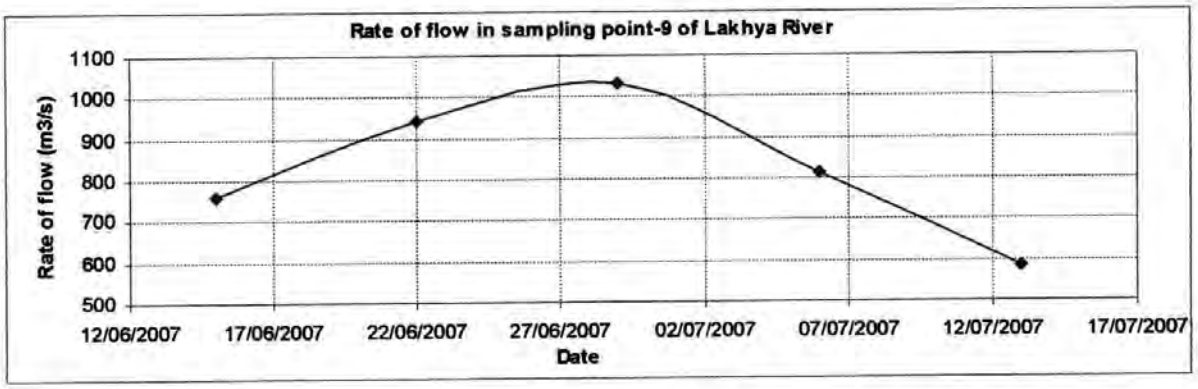


Figure 6.4 Variation of flow rate at the sampling point-9 along the Lakhya River

6.3 Analysis of water quality along the Lakhya River to assess impact of Polash and Ghorasal urea fertilizer factories effluent

6.3.1 Biochemical Oxygen Demand (BOD)

The level of Biochemical Oxygen Demand (BOD_5) was 8-11 mg/l (9.2±1.16mg/l) in the sampling point-1. In the sampling point-6 it was 9-11 mg/l (10±0.89mg/l) in which 146.97-348.19 kg/day (226.18±66.26 kg/day) BOD_5 discharged from sampling point-5. In the sampling point-8, it was 11-14mg/l (12.4±1.01 mg/l) in which 2518.3-3094.42 kg/day (2902.92±211.31 kg/day) BOD_5 discharged from sampling point-4 and 7. For the dilution factor the BOD_5 reduced in the sampling point-9 and it was 10-13 mg/l (11.4±1.01 mg/l). The levels of BOD_5 along Lakhya River are shown in Figure 6.5 and Table A6.2.

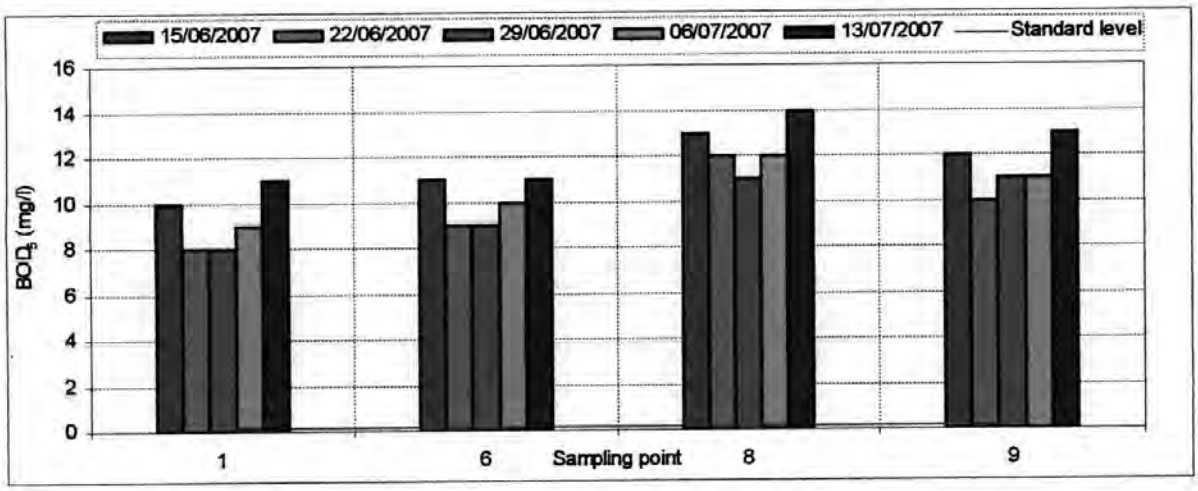


Figure 6.5 Variation of BOD_5 in mg/l along the Lakhya River

6.3.2 Chemical Oxygen Demand (COD)

The level of Chemical Oxygen Demand (COD) was 12-19 mg/l (15.8±2.78 mg/l) in the sampling point-1. In the sampling point-6 it was 15-21 mg/l (18±2.52 mg/l) in which 258.94-595.29 kg/day (369.49±118.68 kg/day) COD discharged from sampling point-5. In the sampling point-8 it was 18-23 mg/l (20.6±2.24 mg/l) in which 4455.64-4644.45 kg/day (4543.72±67.82 kg/day) COD discharged from sampling point-4 and 7. For the dilution factor the COD reduced in the sampling point-9 and it was 17-22 mg/l (19.6±2.24 mg/l). The levels of COD along Lakhya River are shown in Figure 6.6 and Table A6.3.

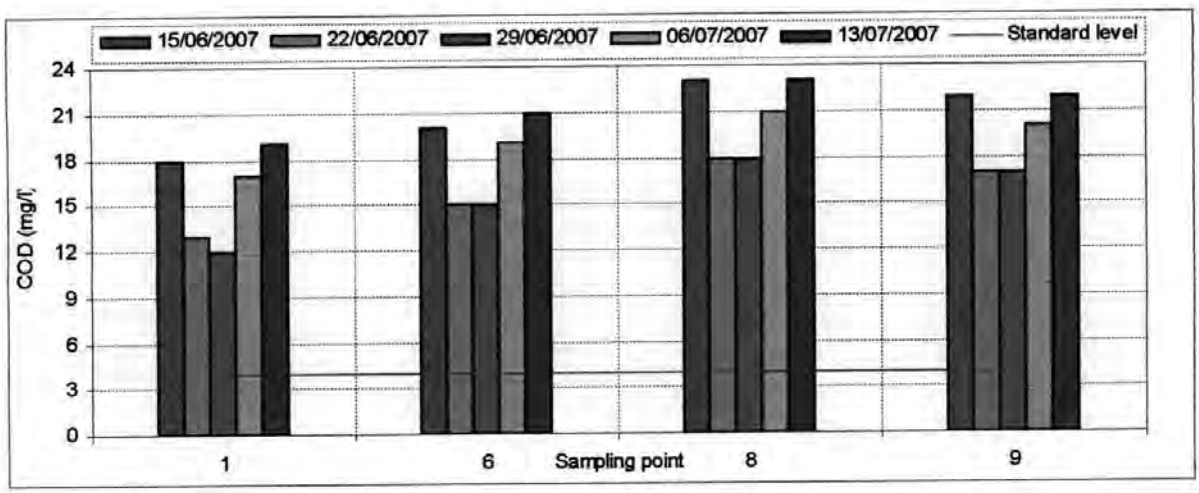


Figure 6.6 Variations of COD in mg/l along the Lakhya River

6.3.2 Dissolved Oxygen (DO)

The level of Dissolved Oxygen (DO) was 4-4.8 mg/l (4.476±0.26 mg/l) in the sampling point-1. In the sampling point-6 it was 3.9-4.4 mg/l (4.08±0.19 mg/l) due to pollution load discharged from sampling point-5. In the sampling point-8 it was 3.78-4.1 mg/l (3.9±0.12 mg/l) due to pollution load discharged from sampling point-4 and 7. For the dilution factor pollution load reduced, so DO increased in the sampling point-9 and it was 3.81-4.2 mg/l (3.948±0.14 mg/l). The levels of DO along Lakhya River are shown in Figure 6.7 and Table A6.4.

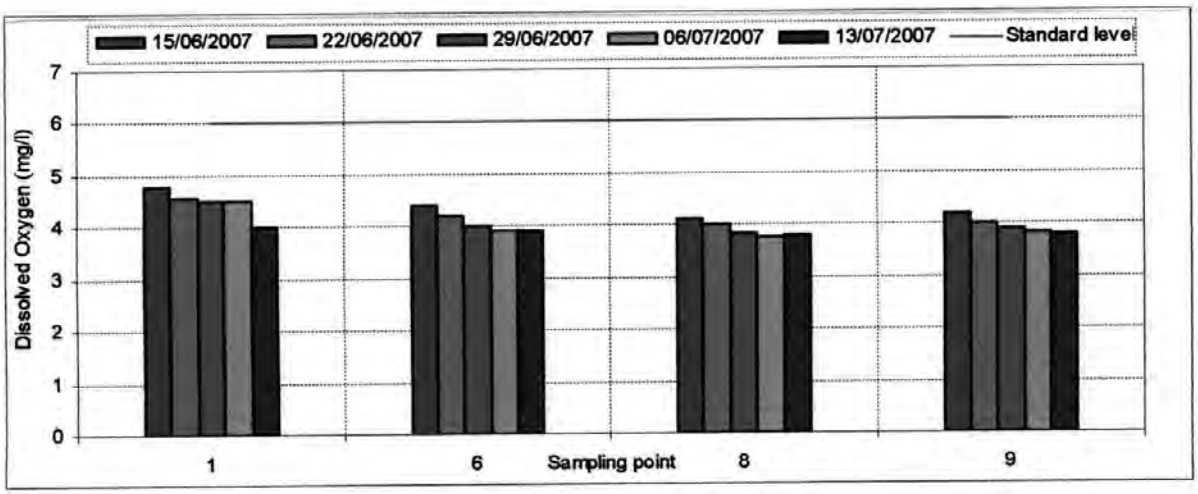


Figure 6.7 Variation of DO in mg/l along the Lakhya River

6.3.3 pH

10959

The level of pH was 7.5-7.8 (7.66±0.102) in the sampling point-1. In the sampling point-6 it was 7.9-8.3 (8.1±0.12) due to pollution load discharge from sampling point-5. In the sampling point-8 it was 8-8.4 (8.18±0.13) due to pollution load discharge from sampling point-4 and 7. For the dilution factor pollution load decreased at the sampling point-9, so pH decreased at that point and it was 8.1-8.3 (8.16±0.08). The levels of pH along Lakhya River are shown in Figure 6.8 and Table A6.5.

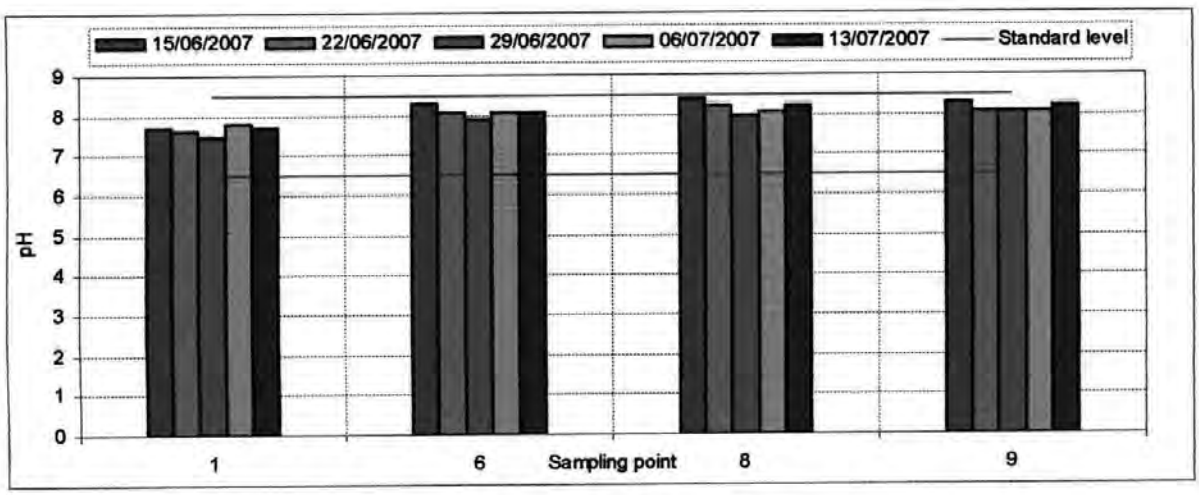


Figure 6.8 Variation of pH along the Lakhya River

6.3.4 Temperature

The level of Temperature was 28-31.4 °C (29.68±1.13 °C) in the sampling point-1. In the sampling point-6 it was 28-32 °C (30.4±1.43°C) due to pollution load in high temperature discharged from sampling point-5. In the sampling point-8 it was 28.2-31.7 °C (30.14±1.26 °C) due to pollution load in high temperature discharged from sampling point-4 and 7. In the sampling point-9, it was 28.1-30.5 °C (29.72±1.04 °C). The levels of Temperature along Lakhya River are shown in Figure 6.9 and Table A6.6.

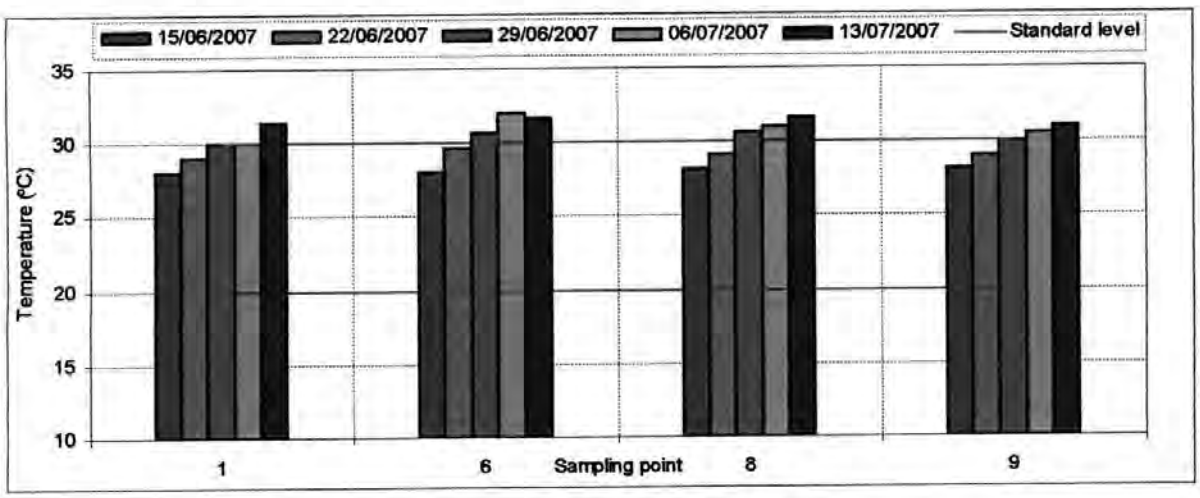


Figure 6.9 Variation of Temperature in °C along the Lakhya River

6.3.5 Total Ammonia (NH_3-N + NH_4-N)

The concentration of Total Ammonia was 0.685-0.71 mg/l (0.69±0.009mg/l) in the sampling point-1. In the sampling point-6 it was 0.97-1.19 mg/l (1.086±0.079 mg/l) due to 7368-11203 kg/day (8624±1344 kg/day) total Ammonia discharged from sampling point-5. In the sampling point-8, it was 1.09-1.30 mg/l (1.2±0.072 mg/l) due to 8808-10467 kg/day (9577±533 kg/day) total Ammonia discharged from sampling point-4 and 7. For the dilution factor the total Ammonia reduced in the sampling point-9 and it was 0.95-1.15 mg/l (1.05±0.07 mg/l). It was observed that fertilizer factories are the major sources of Total Ammonia discharged into the Lakhya River in the study area. The concentration of total Ammonia in sampling point-9 is greater than the concentration of Total Ammonia in sampling point-1. This increment is fully responsible the Ammonia load discharged from fertilizer factories. So the Ammonia load discharged from fertilizer factories has a large

impact on the Lakhya River water quality. The levels of total Ammonia along Lakhya River are shown in Figure 6.10 and Table A6.7.

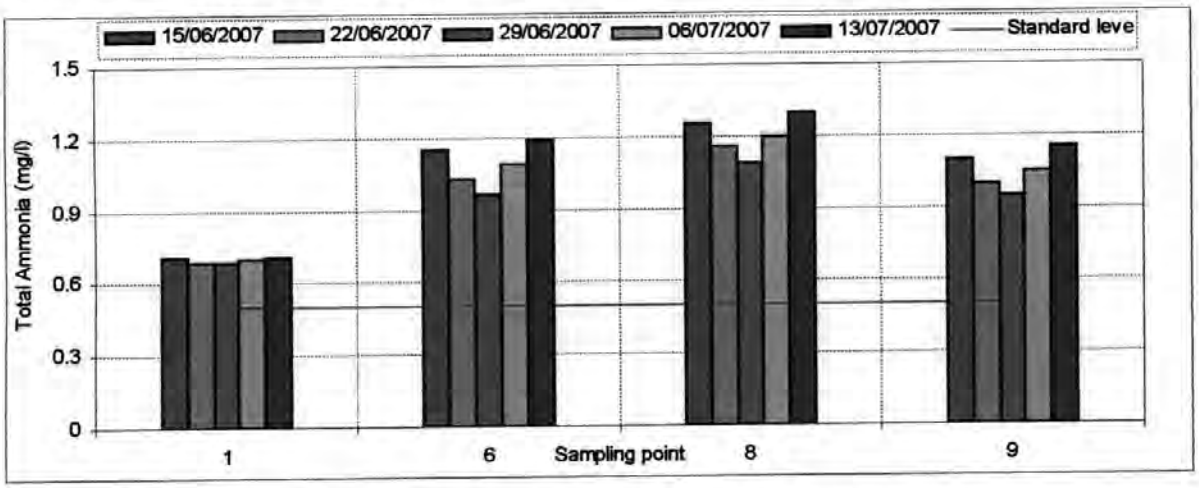


Figure 6.10 Variation of Total Ammonia in mg/l along the Lakhya River

6.3.6 Ammonia as Nitrogen (NH_3-N)

The concentration of Ammonia as Nitrogen (NH_3-N) was 0.01-0.02 mg/l (0.016±0.0004mg/l) in the sampling point-1. In the sampling point-6 it was 0.08-0.11 mg/l (0.074±0.022 mg/l) due to 4975.23-6598.68 kg/day (5643.73±590.45 kg/day) NH_3-N discharged from sampling point-5. In the sampling point-8 it was 0.06-0.15 mg/l (0.096±0.03 mg/l) due to 2322.54-5265.65 kg/day (3542.03±1080.86 kg/day) NH_3-N discharged from sampling point-4 and 7. For the dilution factor the NH_3-N reduced in the sampling point-9 and it was 0.06-0.11 mg/l (0.078±0.01 mg/l). It was observed that fertilizer factories are the major sources of Ammonia (NH_3-N) discharged into the Lakhya River in the study area. The concentration of Ammonia in sampling point-9 is greater than the concentration of Ammonia in sampling point-1. This increment occured due to the Ammonia discharged from fertilizer factories. So the Ammonia discharged from fertilizer factories has a large impact on the Lakhya River water quality. The levels of NH_3-N along Lakhya River are shown in Figure 6.11 and Table A6.8.

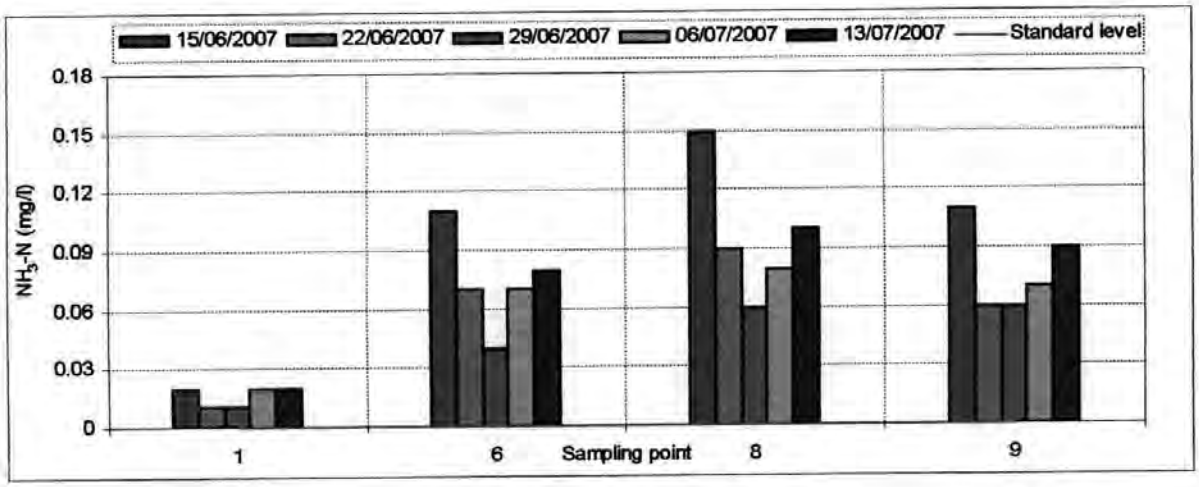


Figure 6.11 Variation of NH_3-N in mg/l along the Lakhya River

6.3.8 Ammonium as Nitrogen (NH_4-N)

The concentration of Ammonium as Nitrogen (NH_4-N) was 0.67-0.69 mg/l (0.68±0.007mg/l) in the sampling point-1. In the sampling point-6 it was 0.93-1.11 mg/l (1.01±0.06 mg/l) due to 1903.08-5988.22 kg/day (2980.78±1541.86 kg/day) NH_4-N discharged from sampling point-5. In the sampling point-8 it was 1.03-1.20 mg/l (1.104±0.05 mg/l) due to 5201.7-7064.64 kg/day (6035.72±687.03 kg/day) NH_4-N discharged from sampling point-4 and 7. For the dilution factor the NH_4-N reduced in the sampling point-9 and it was 0.89-1.06 mg/l (0.97±0.05 mg/l). It was observed that fertilizer factories are the major sources of Ammonium (NH_3-N) discharged into the Lakhya River in the study area. The concentration of Ammonium in sampling point-9 is greater than the concentration of Ammonium in sampling point-1. This increment occurred due to the Ammonium load discharged from fertilizer factories. So the Ammonium load discharged from fertilizer factories has a large impact on the Lakhya River water quality. The levels of NH_4-N along Lakhya River are shown in Figure 6.12 and Table A6.9.

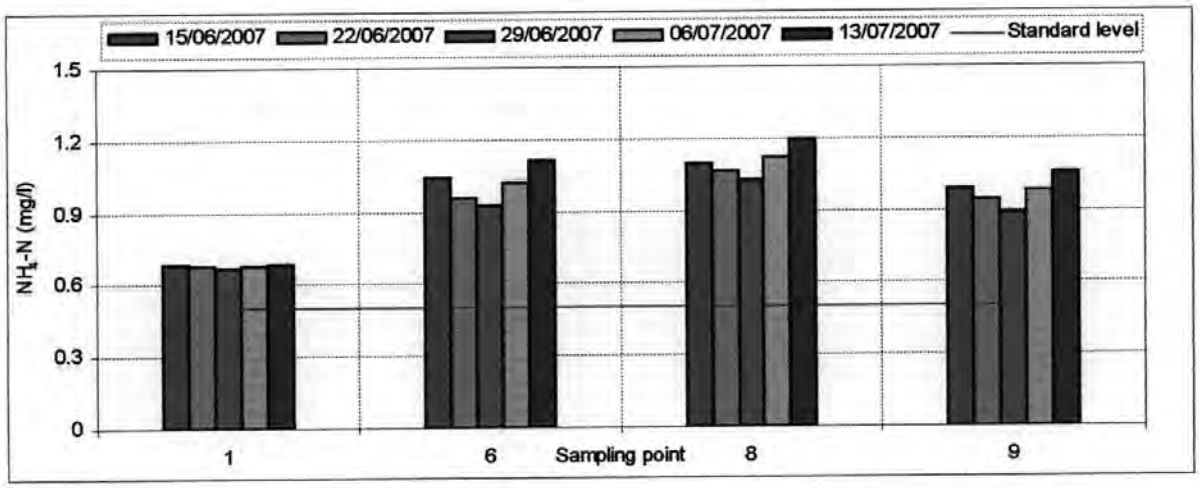


Figure 6.12 Variation of NH_4-N in mg/l along the Lakhya River

6.3.9 Total Solids (TS)

The concentration of Total Solids (TS) was 179-247 mg/l (200±24.88mg/l) in the sampling point-1. In the sampling point-6 it was 193-261 mg/l (220±22.82 mg/l), in which 1523-3077 kg/day (1908±594 kg/day) TS discharged from sampling point-5. In the sampling point-8 it was 220-286 mg/l (251±21.6mg/l) in which 5925-7302 kg/day (6816±606.69 kg/day) TS discharged from sampling point-4 and 7. Total solids were accumulated in the downstream, for this, the value of TS were increased in the sampling point-9 and it were 237-298 mg/l (267.6±22.08 mg/l). The concentrations of Total Solids (TS) along Lakhya River are shown in Figure 6.13 and Table A6.10.

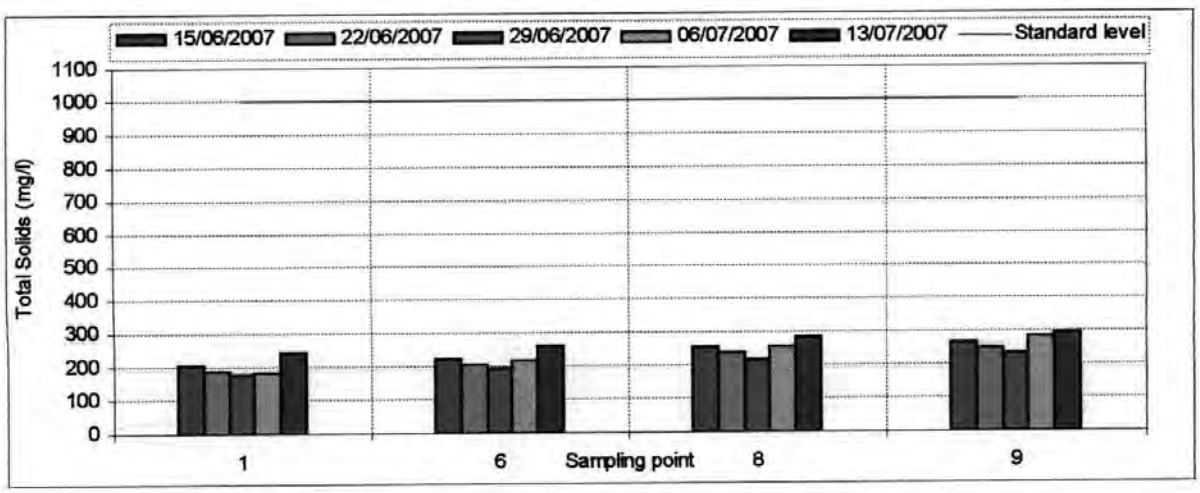


Figure 6.13 Variations of Total Solids in mg/l along the Lakhya River

6.3.10 Total Suspended Solids (TSS)

The concentration of Total Suspended Solids (TSS) was 19-41 mg/l (30±7mg/l) in the sampling point-1. In the sampling point-6 it was 20-45 mg/l (33.2±8.65 mg/l) in which 1394-2623 kg/day (2060±451 kg/day) TSS discharged from sampling point-5. In the sampling point-8 it was 26-58 mg/l (43.2±11.56mg/l) in which 118-752 kg/day (348±213 kg/day) TSS discharged from sampling point-4 and 7. Total suspended solids were accumulated in the downstream, for this, the value of TSS were increased in the sampling point-9 and it were 27-62 mg/l (46±12.55 mg/l). The concentrations of Total Suspended Solids (TSS) along Lakhya River are shown in Figure 6.14 and Table A6.11.

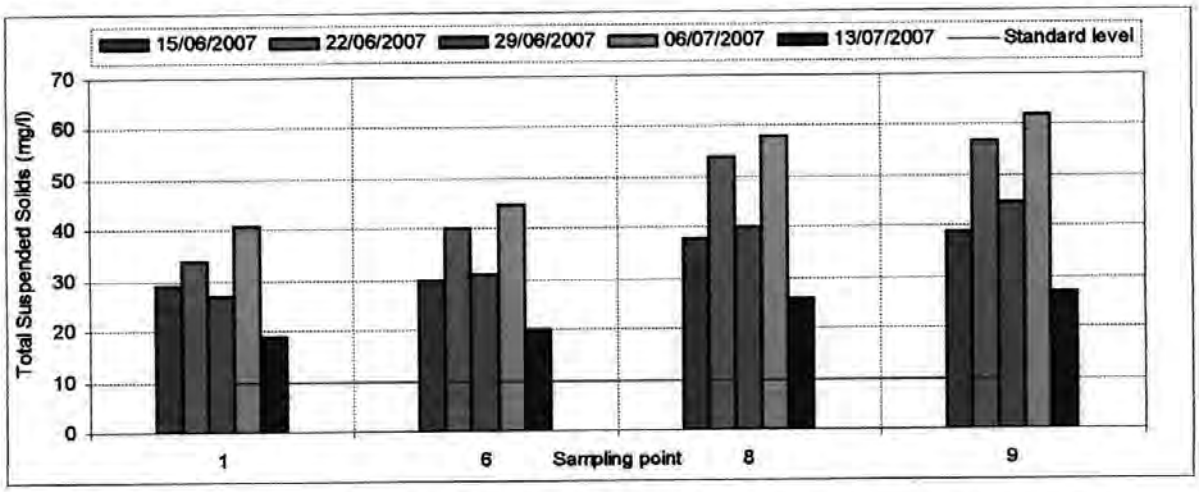


Figure 6.14 Variations of Total Suspended Solids in mg/l along the Lakhya River

6.3.11 Total Dissolved Solids (TDS)

The concentration of Total Dissolved Solids (TDS) was 141-228 mg/l (170±30mg/l) in the sampling point-1. In the sampling point-6 it was 162-245 mg/l (190.2±30.91 mg/l) in which 1394-2623 kg/day (2060±451 kg/day) TDS discharged from sampling point-5. In the sampling point-8 it was 181-257 mg/l (207.4±27.8mg/l) in which 118-752 kg/day (348±213 kg/day) TDS discharged from sampling point-4 and 7. Total suspended solids were accumulated in the downstream, for this, the value of TDS were increased in the sampling point-9 and it were 192-271 mg/l (221.6±28.7 mg/l). The concentrations of Total Dissolved Solids (TDS) along Lakhya River are shown in Figure 6.15 and Table A6.12.

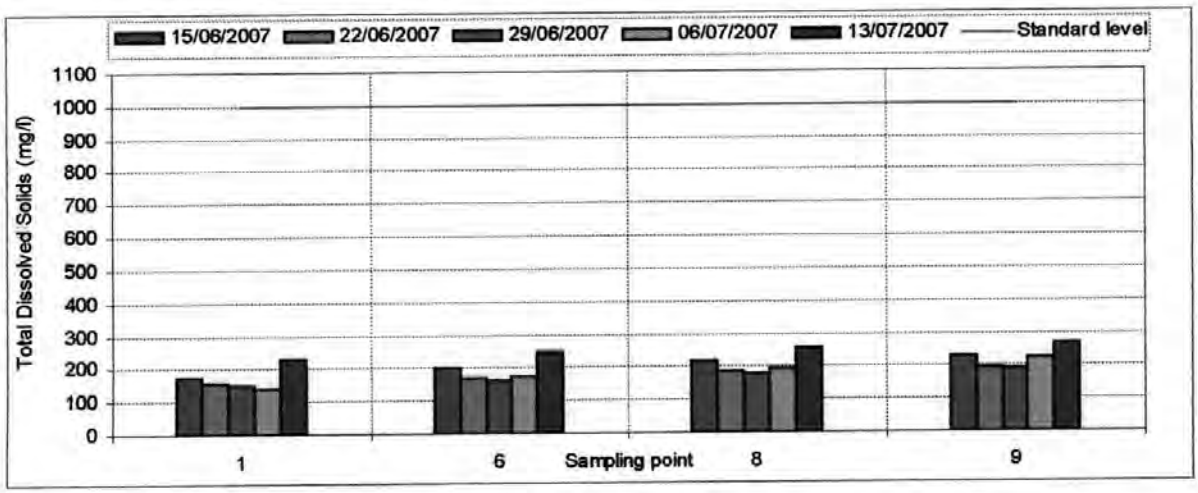


Figure 6.15 Variation of Total Dissolved Solids in mg/l along the Lakhya River

6.4 Analysis of Pollution Load along the Lakhya River to assess impact of Polash and Ghorasal urea fertilizer factories effluent

6.4.1 Biochemical Oxygen Demand (BOD)

The level of pollution load along the Lakhya River of Biochemical Oxygen Demand (BOD_5) was 552878-713615 kg/day (640523±51939 kg/day) in the sampling point-1. In the sampling point-6 it was 553607-803513 kg/day (702374±82048 kg/day) in which 146.97-348.19 kg/day (226.18±66.26 kg/day) BOD_5 discharged from sampling point-5. In the sampling point-8 it was 705054-982497 kg/day (871789±102518 kg/day) in which 2518.3-3094.42 kg/day (2902.92±211.31 kg/day) BOD_5 discharged from sampling point-4 and 7. In the sampling point-9, it was 655124-982923 kg/day (802362±105472 kg/day). It was shown that there was insignificant impact of pollution load of BOD_5 discharged from fertilizer factories. The levels of BOD_5 along Lakhya River are shown in Figure 6.16 and Table A6.13.

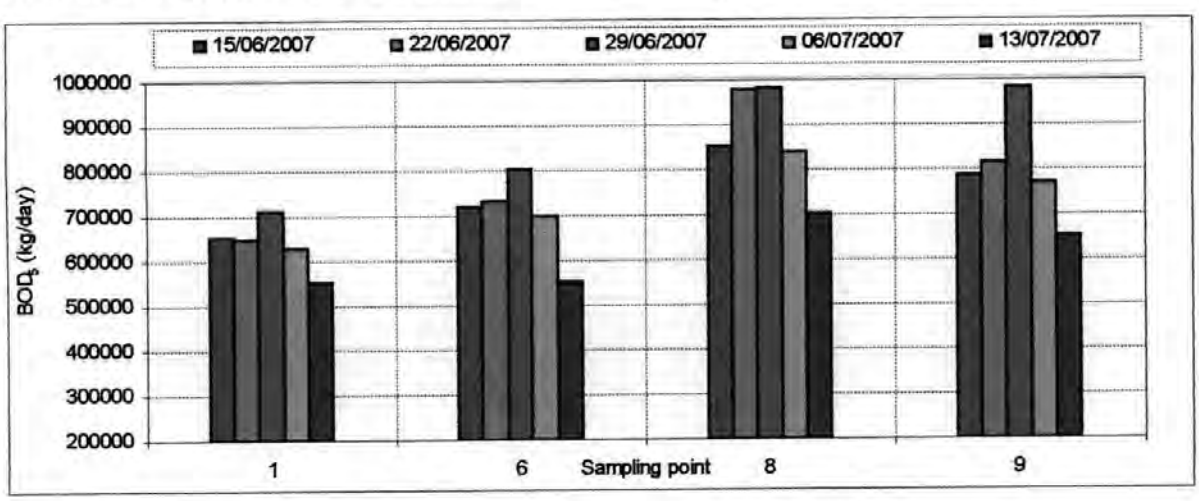


Figure 6.16 Variation of BOD_5 in kg/day along the Lakhya River

6.4.2 Chemical Oxygen Demand (COD)

The level of pollution load along the Lakhya River of Chemical Oxygen Demand (COD) was 954971-1188933 kg/day (1090493±86782 kg/day) in the sampling point-1. In the sampling point-6 it was 1056886-1339188 kg/day (1252013±106198 kg/day) in which 258.94-595.29 kg/day (369.49±118.68 kg/day) COD discharged from sampling point-5. In the sampling point-8 it was 1158303-1607722 kg/day (1442595±150924 kg/day) in which 4455.64-4644.45 kg/day (4543.72±67.82 kg/day) COD discharged from sampling point-4 and 7. In the sampling point-9, it was 1108672-1519062 kg/l (1371856±139415 kg/day). It was shown that there was insignificant impact of pollution load of COD discharged from fertilizer factories. The levels of COD along Lakhya River are shown in Figure 6.17 and Table A6.14.

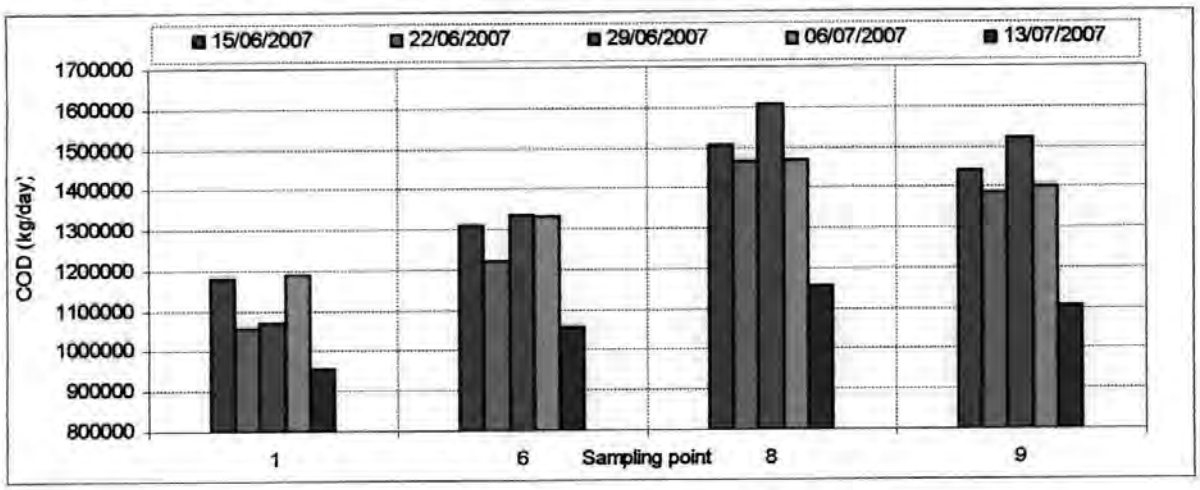


Figure 6.17 Variation of COD in kg/day along the Lakhya River

6.4.3 Total Ammonia (NH_3-N + NH_4-N)

The level of pollution load along the Lakhya River of Total Ammonia was 35686-61103 kg/day (49663±8707 mg/l) in the sampling point-1. In the sampling point-6 it was 59890-86601 kg/day (76427±8309 kg/day) due to 7368-11203 kg/day (8624±1344 kg/day) total Ammonia discharged from sampling point-5. In the sampling point-8 it was 65469-97357 kg/day (84685±11257 kg/day) due to 8808-10467 kg/day (9577±533 kg/day) total Ammonia discharged from sampling point-4 and 7. For the dilution factor the total Ammonia reduced in the sampling point-9 and it was 57953-84889 kg/day (74030±9336 kg/day). It was observed that fertilizer factories are the major sources of Total Ammonia load discharged in Lakhya River in the study area. The amount of total Ammonia load in sampling point-9 is greater

than the load of Total Ammonia in sampling point-1. This increment occurred due to the Ammonia load discharged from fertilizer factories. So the Ammonia load discharged from fertilizer factories has a large impact on the Lakhya River water quality. The levels of total Ammonia along the Lakhya River are shown in Figure 6.18 and Table A6.15.

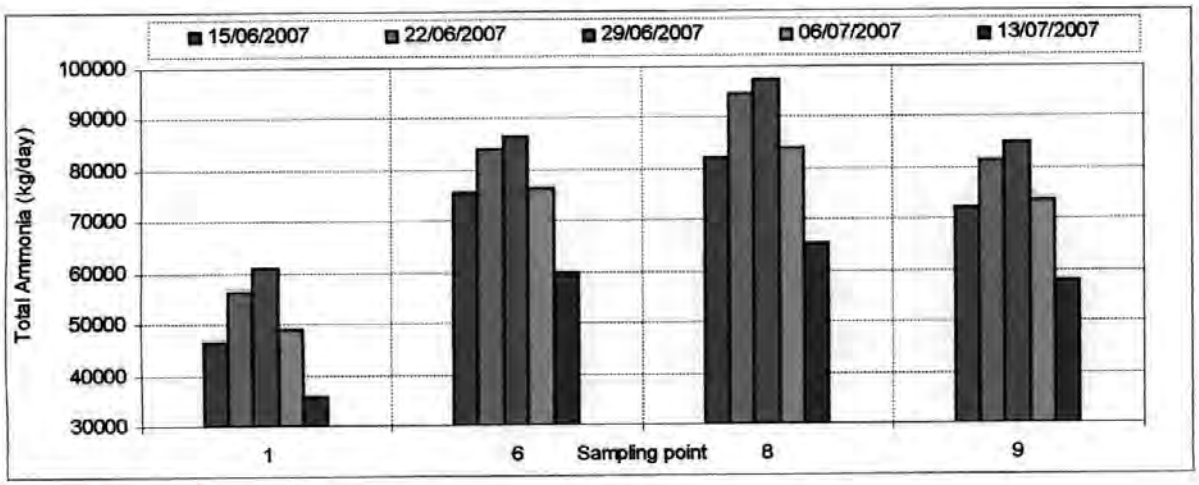


Figure 6.18 Variation of Total Ammonia in kg/day along the Lakhya River

6.4.4 Ammonia as Nitrogen (NH_3-N)

The pollution load of Ammonia as Nitrogen (NH_3-N) was 814-1399 kg/day (1084±231 kg/day) in the sampling point-1. In the sampling point-6 it was 3571-7215 kg/day (5083±1293 kg/day) due to 4975.23-6598.68 kg/day (5643.73±590.45 kg/day) NH_3-N discharged from sampling point-5. In the sampling point-8 it was 5036-9840 kg/day (6635±1788 kg/day) due to 2322.54-5265.65 kg/day (3542.03±1080.86 kg/day) NH_3-N discharged from sampling point-4 and 7. For the dilution factor the NH_3-N reduced in the sampling point-9 and it was 4535-7217 kg/day (5383±954 kg/day). It was observed that fertilizer factories are the major sources of Ammonia load (NH_3-N) discharged into the Lakhya River in the study area. The amount of Ammonia load in sampling point-9 is greater than the load of Ammonia in sampling point-1. This increment occurred due to the Ammonia load discharged from fertilizer factories. So the Ammonia load discharged from fertilizer factories has a large impact on the Lakhya River water quality. The pollution load of NH_3-N along Lakhya River is shown in Figure 6.19 and Table A6.16.

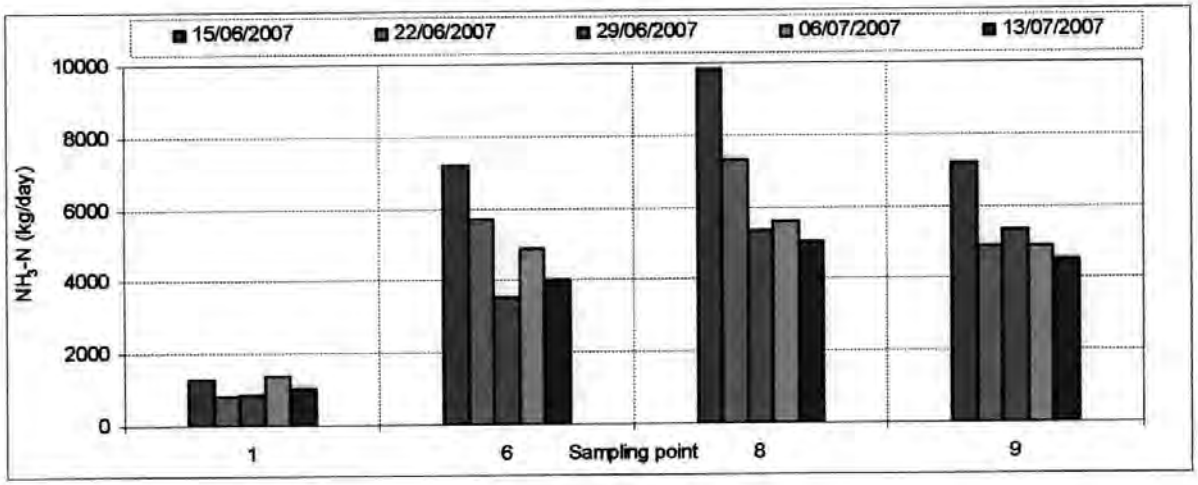


Figure 6.19 Variation of Ammonia as Nitrogen (NH_3-N) in kg/day along the Lakhya River

6.4.5 Ammonium as Nitrogen (NH_4-N)

The pollution load of Ammonium as Nitrogen (NH_4-N) was 34681-59765 kg/day (48515±8670 kg/day) in the sampling point-1. In the sampling point-6 it was 55864-83030 kg/day (71344±9300 kg/day) due to 1903.08-5988.22 kg/day (2980.78±1541.86 kg/day) NH_4-N discharged from sampling point-5. In the sampling point-8 it was 60433-91997 kg/day (78050±11161 kg/day) due to 5201.7-7064.64 kg/day (6035.72±687.03 kg/day) NH_4-N discharged from sampling point-4 and 7. For the dilution factor the NH_4-N reduced in the sampling point-9 and it was 53418-79527 kg/day (68648±9245 kg/day). It was observed that fertilizer factories are the major sources of Ammonium load (NH_3-N) discharged into the Lakhya River in the study area. The amount of Ammonium load in sampling point-9 is greater than the load of Ammonium in sampling point-1. This increment occurred due to the Ammonium load discharged from fertilizer factories. So the Ammonium load discharged from fertilizer factories has a large impact on the Lakhya River water quality. The pollution load of NH_4-N along the Lakhya River is shown in Figure 6.20 and Table A6.17.

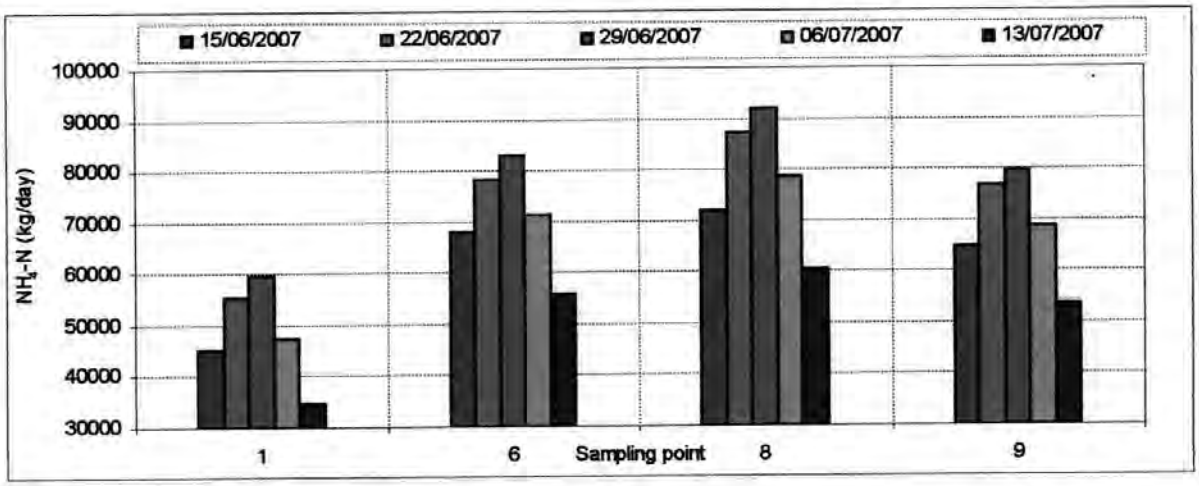


Figure 6.20 Variation of Ammonium as Nitrogen (NH_4-N) in kg/day along the Lakhya River

6.4.6 Total Solids (TS)

The level of pollution load of Total Solids (TS) was 12414626-15967134 kg/day (14002508±1444285 kg/day) in the sampling point-1. In the sampling point-6 it was 13135585-17230884 kg/day (15395465±1501169 kg/day) in which 1523-3077 kg/day (1908±594 kg/day) TS discharged from sampling point-5. In the sampling point-8 it was 14403247-19649938 kg/day (17683404±1956566 kg/day) in which 5925-7302 kg/day (6816±606.69 kg/day) TS discharged from sampling point-4 and 7. Total solids were accumulated in the downstream, for this, the load of TS were increased in the sampling point-9 and it were 15017466-21177516 kg/day (18831382±2269732 kg/day). It was shown that the pollution load of TS discharged from sampling point 5, 4 and 7 were negligible as compared to the load discharged from residential area on the bank of the Lakhya river. So it can be concluded that there was insignificant impact of pollution load of TS discharged from fertilizer factories. The level of Total Solids (TS) along Lakhya River is shown in Figure 6.21 and Table A6.18.

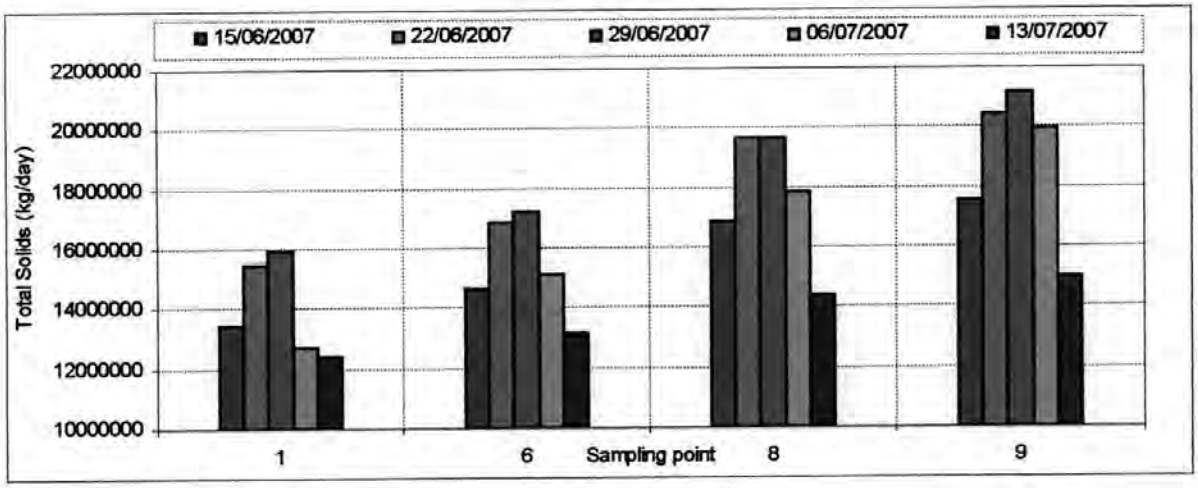


Figure 6.21 Variation of Total Solids in kg/day along the Lakhya River

6.4.7 Total Suspended Solids (TSS)

The level of Total Suspended Solids (TSS) was 954971-2867428 kg/day (2179768±699440 kg/day) in the sampling point-1. In the sampling point-6 it was 1006558-3257035 kg/day (2430154±843632 kg/day) in which 1394-2623 kg/day (2060±451 kg/day) TSS discharged from sampling point-5. In the sampling point-8 it was 1309386-4398998 kg/day (3167783±1130850 kg/day) in which 118-752 kg/day (348±213 kg/day) TSS discharged from sampling point-4 and 7. Total suspended solids were accumulated in the downstream, for this, the load of TSS were increased in the sampling point-9 and it were 1360643-4645510 kg/day (3386845±1241162 kg/day). It was shown that the pollution load of TSS discharged from sampling point 5, 4 and 7 were negligible as compared to the load discharged from residential area on the bank of the Lakhya river. So it can be concluded that there was negligible impact of pollution load of TS discharged from fertilizer factories. The level of Total Suspended Solids (TSS) along the Lakhya River is shown in Figure 6.22 and Table A6.19.

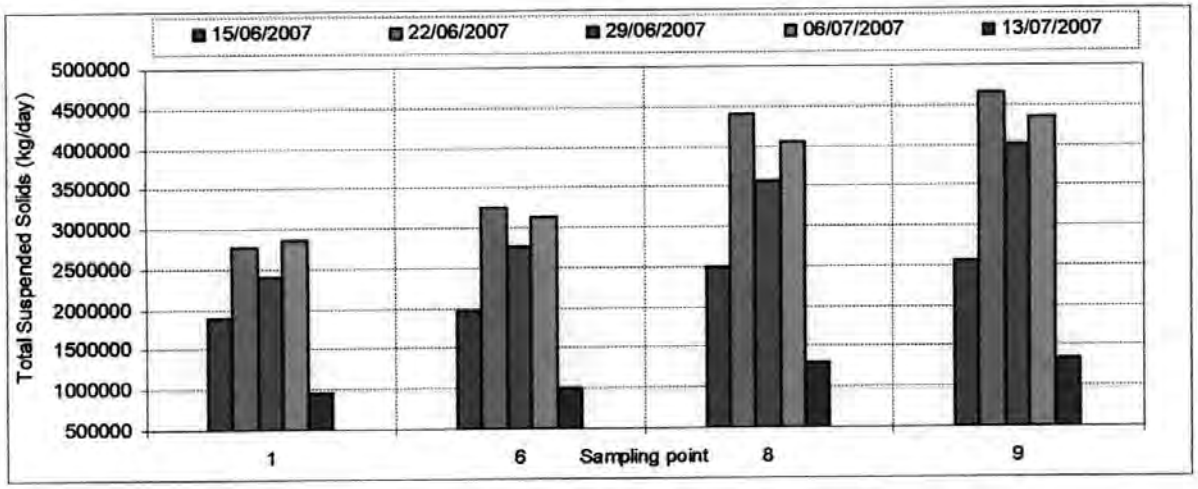


Figure 6.22 Variation of Total Suspended Solids in kg/day along the Lakhya River

6.4.8 Total Dissolved Solids (TDS)

The level of pollution load of Total Dissolved Solids (TDS) was 9861153-13558684 kg/day (11822740±1251002 kg/day) in the sampling point-1. In the sampling point-6 it was 12256499-14463229 kg/day (13176508±818925 kg/day) in which 1394-2623 kg/day (2060±451 kg/day) TDS discharged from sampling point-5. In the sampling point-8 it was 12942778-16166540 kg/day (14448096±1147385 kg/day) in which 118-752 kg/day (348±213 kg/day) TDS discharged from sampling point-4 and 7. Total suspended solids were accumulated in the downstream, for this, the load of TDS were increased in the sampling point-9 and it were 13656823-17156469 kg/day (15444538±1143304 kg/day). It was shown that the pollution load of TDS discharged from sampling point 5, 4 and 7 were negligible as compared to the load discharged from residential area on the bank the Lakhya river. So it can be concluded that there was negligible impact of pollution load of TS discharged from fertilizer factories. The level of Total Dissolved Solids (TDS) along the Lakhya River is shown in Figure 6.23 and Table A6.20.

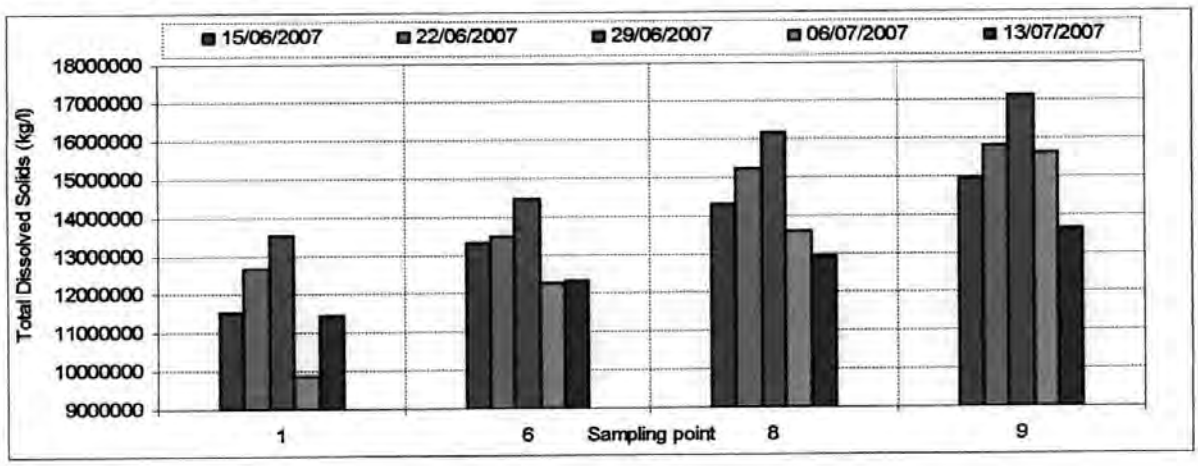


Figure 6.23 Variation of Total Dissolved Solids in kg/day along the Lakhya River

Schematic Diagrams of Water Quality Parameters for Different Sources along the Lakhya River

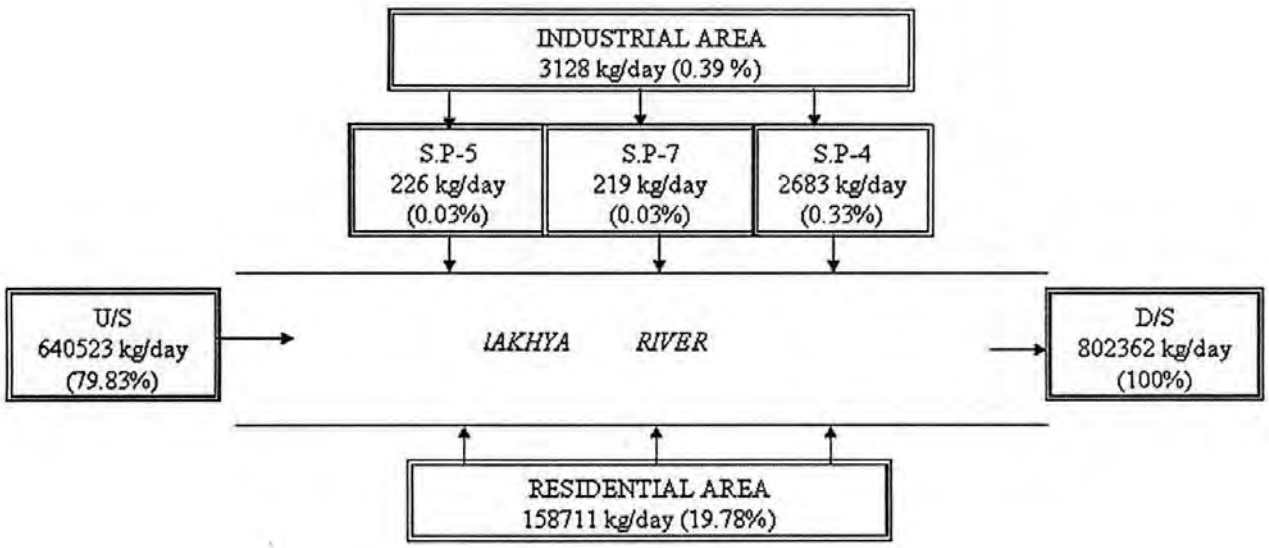


Diagram 6.1: Different sources of BOD_5 along the Lakhya River

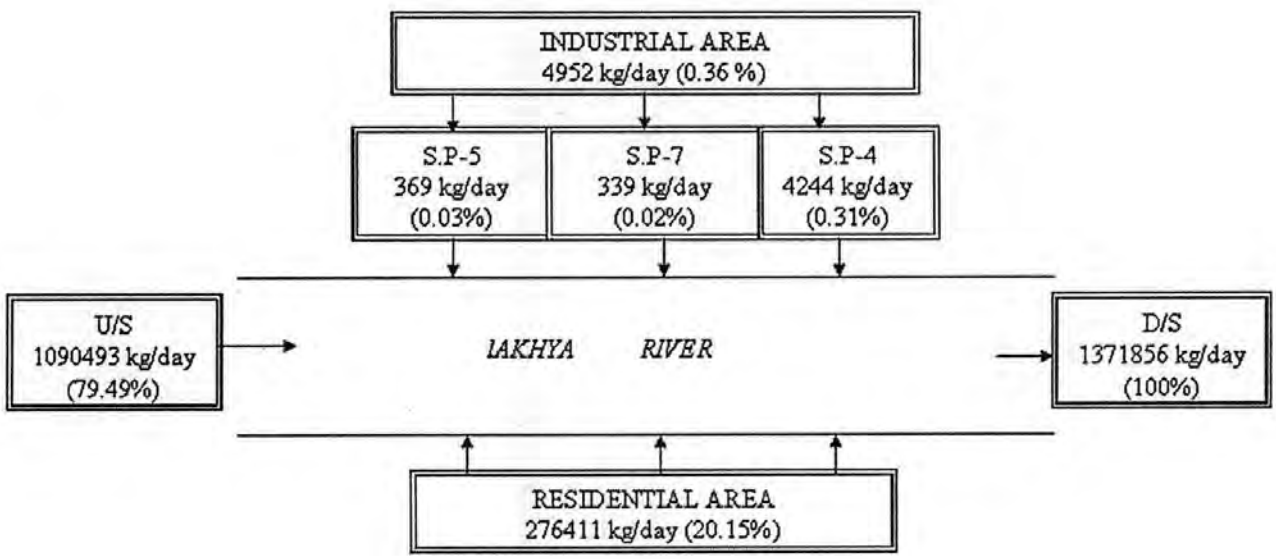


Diagram 6.2: Different sources of COD along the Lakhya River

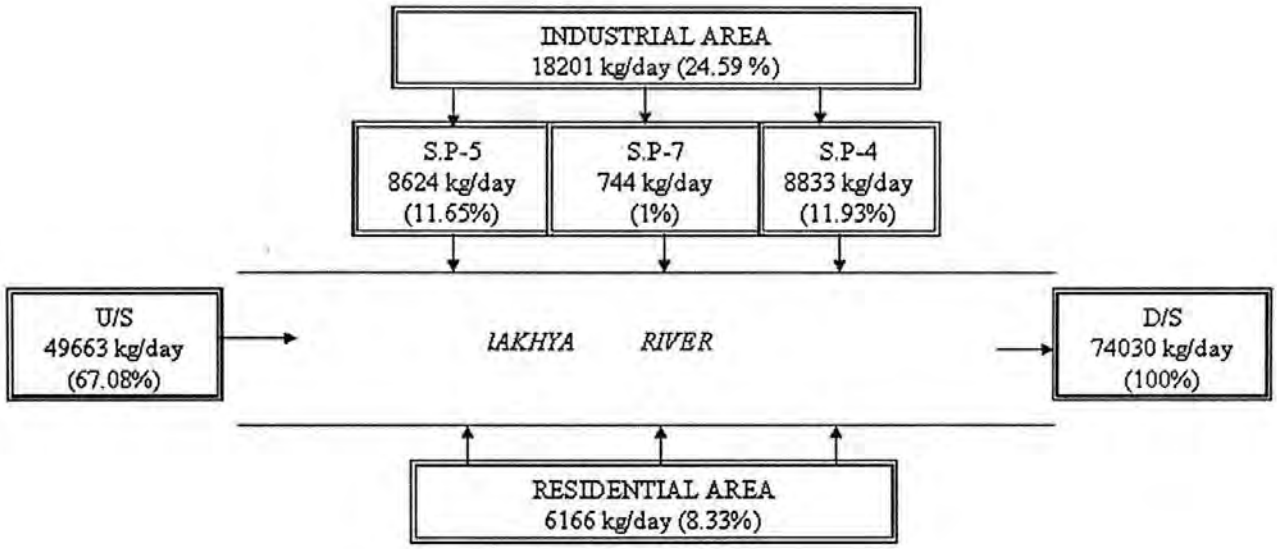


Diagram 6.3: Different sources of Ammonia along the Lakhya River

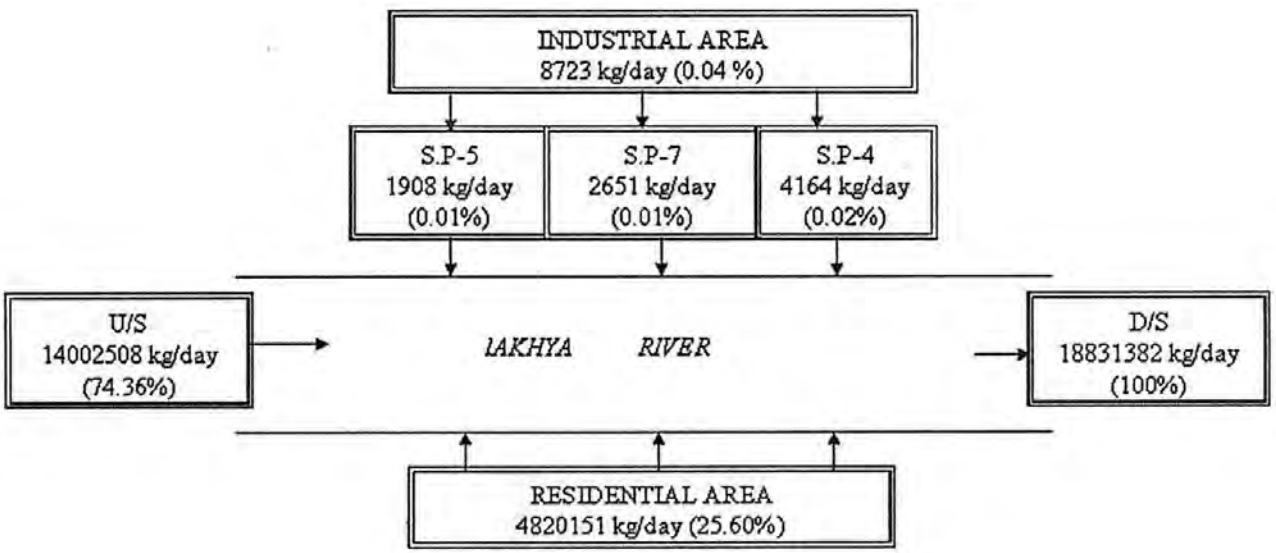


Diagram 6.4: Different sources of Total Solids along the Lakhya River

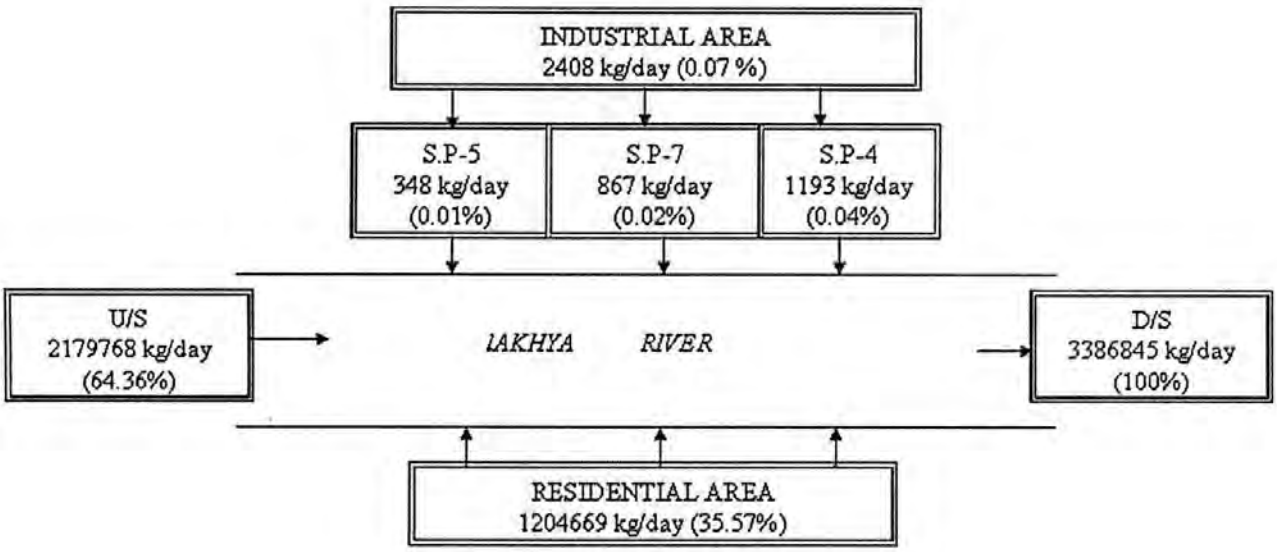


Diagram 6.5: Different sources of Total Suspended Solids along the Lakhya River

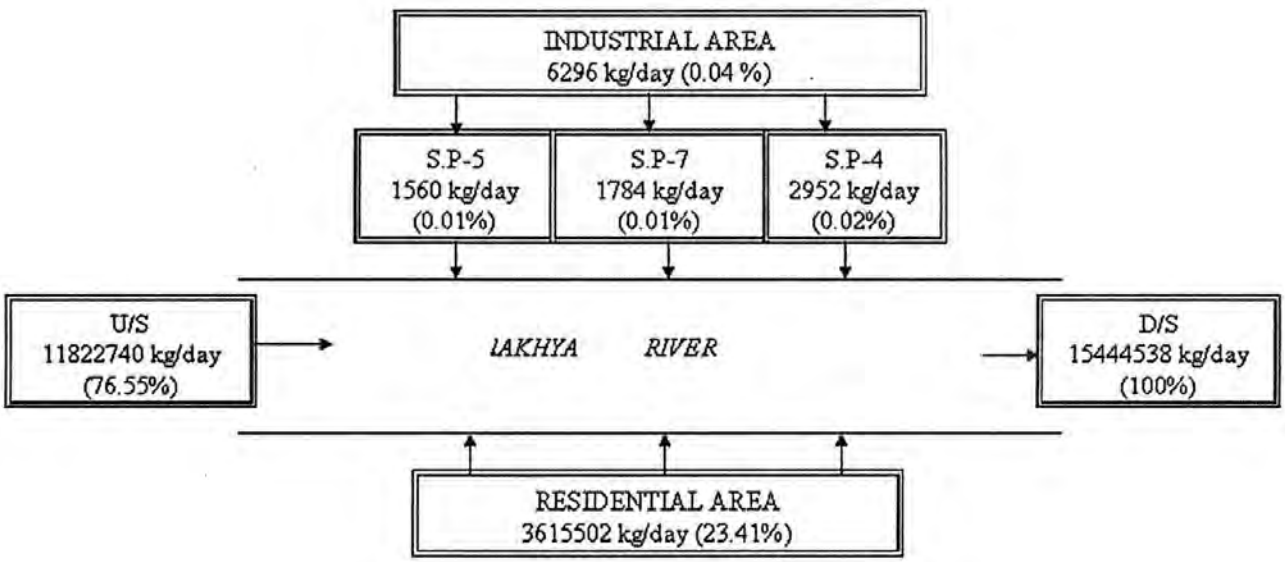


Diagram 6.6: Different sources of Total Dissolved Solids along the Lakhya River

CHAPTER 7

SURFACE WATER QUALITY MODELLING

7.1 Surface Water Quality Modelling for the Lakhya River

The objective of modeling is to find out the relationship between various parameters of the river. In this study, only distance and concentration are considered, taking all other parameters constant. From this 1st order prediction model the concentration at any distance, which can satisfy the standard limit, or even the distance at which the concentration will be zero can be obtained.

The substance decays with time due to chemical reactions, bacterial degradation, radioactive decay, or settling of particulates out of the water column. Substance decays according to a first-order reaction, i.e., the rate of loss of the substance is proportional at any time.

Then the mass balance equation, at steady state, for non-conservative substance is a first-order linear differential equation.

$$\frac{ds}{dx} = -Ks$$

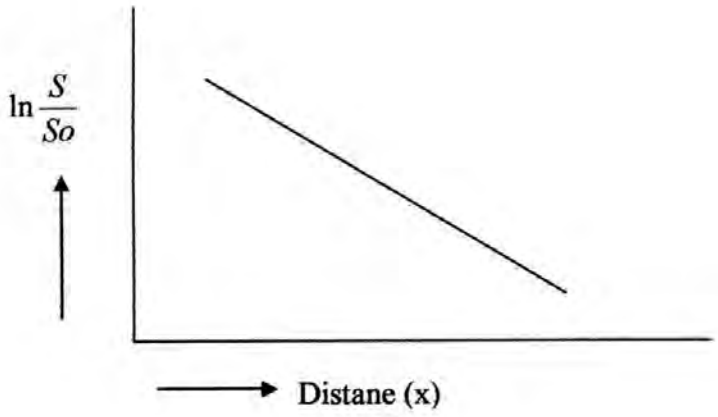
$$\Rightarrow \int_{So}^{S} \frac{ds}{s} = -K \int_{0}^{x} dx$$

$$\Rightarrow \ln S - \ln So = -Kx$$

$$\Rightarrow \ln \frac{S}{So} = -Kx$$

$$\Rightarrow \frac{S}{So} = e^{-Kx}$$

$$S = So\, e^{-Kx}$$



7.2 Effects on river water quality

7.2.1 Biochemical Oxygen Demand (BOD_5)

Highest amount of BOD_5 (12 mg/l) was found at the discharging point of waste into the Lakhya river and was found decreasing with distance at the down streams. The decay rate was found 0.14/km. According to Bangladesh standards the BOD concentration limit is 0.2 mg/l for drinking purpose and 10 mg/l for industrial and irrigation purposes. This implies that the concentration of BOD of the Lakhya River water is not suitable for drinking, industrial or irrigation purposes.

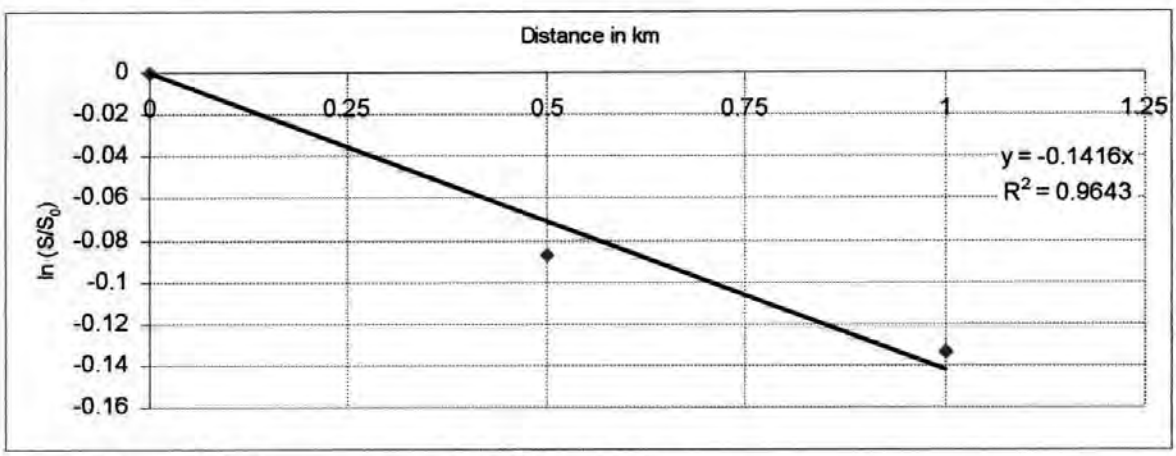


Figure 7.1: Decay constant for BOD_5 with distance

7.2.2 Chemical Oxygen Demand (COD)

Highest amount of COD (21 mg/l) was found at the discharging point of waste into the Lakhya River and was found decreasing with distance at the down streams. The decay rate was found 0.12/km. According to Bangladesh standards for drinking purpose the COD

concentration limit is 4 mg/l. This implies that the concentration of COD of the Lakhya River water is not suitable for drinking, industrial or irrigation purposes.

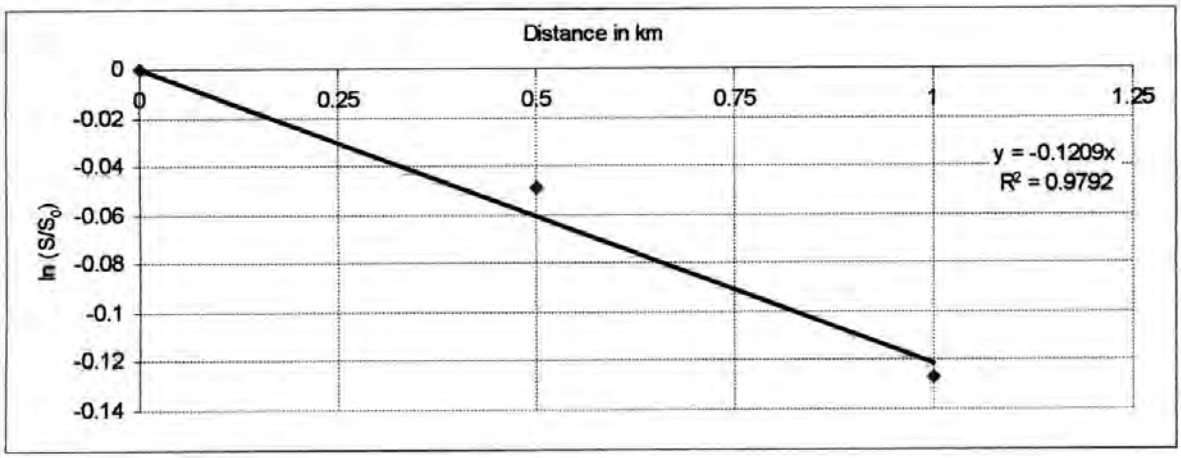


Figure 7.2: Decay constant for COD with distance

7.2.3 Total Ammonia (NH_3-N + NH_4-N)

Highest amount of Total Ammonia (1.2 mg/l) was found at the discharging point of waste into the river Lakhya River and was found decreasing with distance at the down streams. The decay rate was found 0.17/km. Ammonia as nitrogen (NH_3-N) should be 5 mg/l before discharging into inland water but for drinking purpose the limit is 0.5 mg/l. Fertilizer factories are the major sources of Ammonia as nitrogen (NH_3-N) in our study area; so the Polash and Ghorasal fertilizer factories dominate the concentration of Ammonia as nitrogen (NH_3-N) of the Lakhya River water.

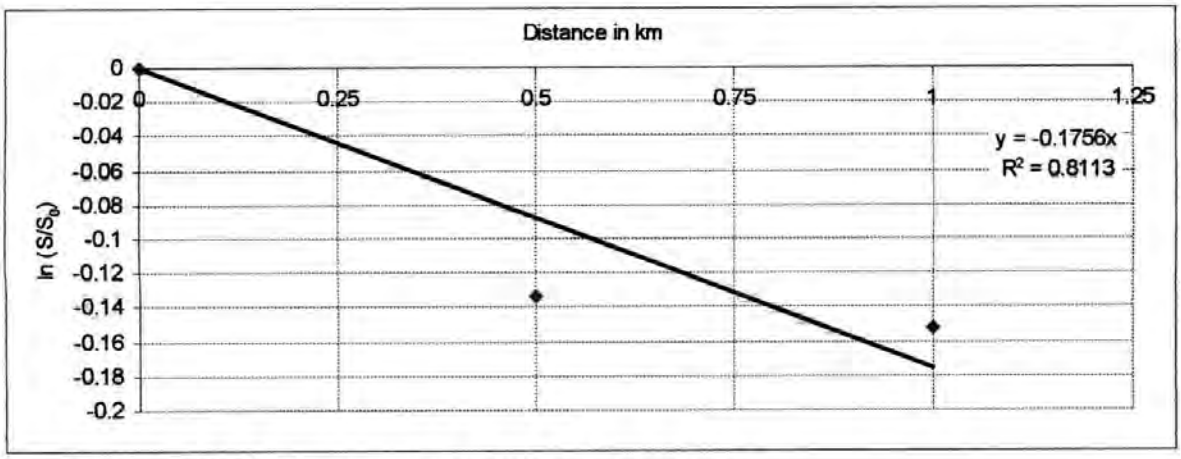


Figure 7.3: Decay constant for NH_3-N with distance

7.3 Relationship between River flow and Concentration of Total Ammonia

Up stream (Sampling point-1)

The flow of Lakhya River at sampling point-1 varied 581.732-1032.429 m^3/s (824±155 m3/s) and the concentration of total Ammonia varied 0.685-0.71 mg/l. From the figure 7.4 it is seen that the relationship between up stream river flow and concentration of total Ammonia is inversely proportional. Monthly average concentration of Total Ammonia generated from this equation (Table A7.1).

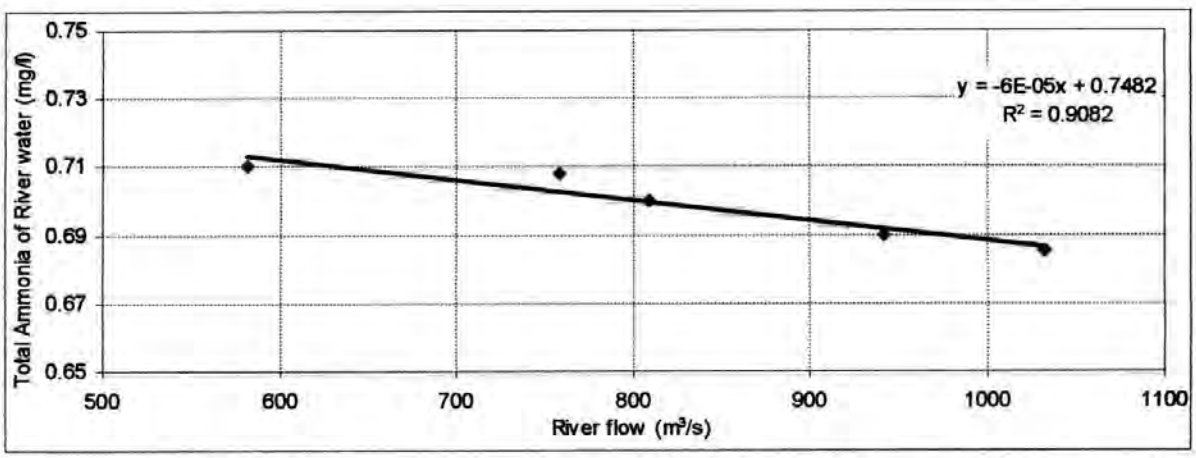


Figure 7.4: Relationship between River flow and Total Ammonia concentration at sampling point-1

Down stream (Sampling point-9)

The flow of Lakhya River at sampling point-9 varied 583.266-1034.22 m^3/s (826±155 m3/s) and the concentration of total Ammonia varied 0.95-1.15 mg/l. From the figure 7.5 it is seen that the relationship between down stream river flow and concentration of total Ammonia is inversely proportional. Monthly average concentration of Total Ammonia generated from this equation (Table A7.2).

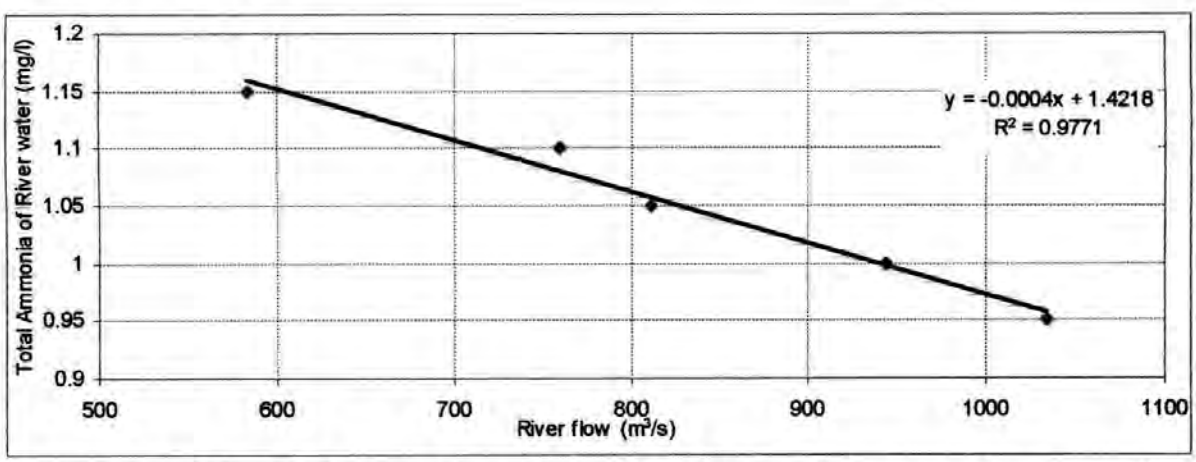


Figure 7.5: Relationship between River flow and Total Ammonia concentration at sampling point-9

7.4 Relationship between River flow and Concentration of Ammonia

Up stream (Sampling point-1)

The flow of Lakhya River at sampling point-1 varied 581.732-1032.429 m^3/s (824±155 m3/s) and the concentration of Ammonia varied 0.01-0.02 mg/l. From the figure 7.6 it is seen that the relationship between up stream river flow and concentration of Ammonia is inversely proportional. Monthly average concentration of Ammonia generated from this equation (Table A7.1).

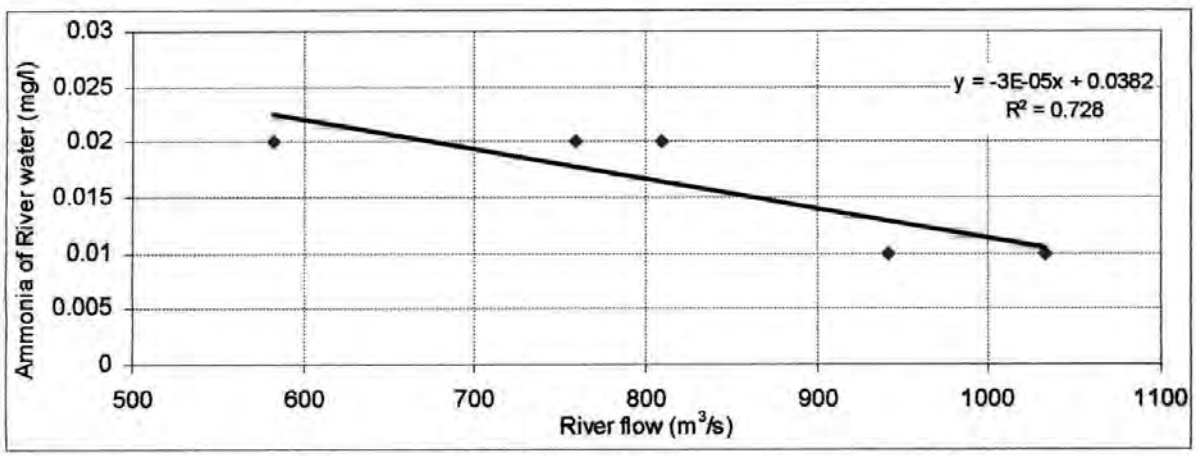


Figure 7.6: Relationship between River flow and Ammonia concentration at sampling point-1

Down stream (Sampling point-9)

The flow of Lakhya River at sampling point-9 varied 583.266-1034.22 m^3/s (826±155 m3/s) and the concentration of Ammonia varied 0.06-0.11 mg/l. From the figure 7.7 it is seen that the relationship between down stream river flow and concentration of Ammonia is inversely proportional. Monthly average concentration of Ammonia generated from this equation (Table A7.2).

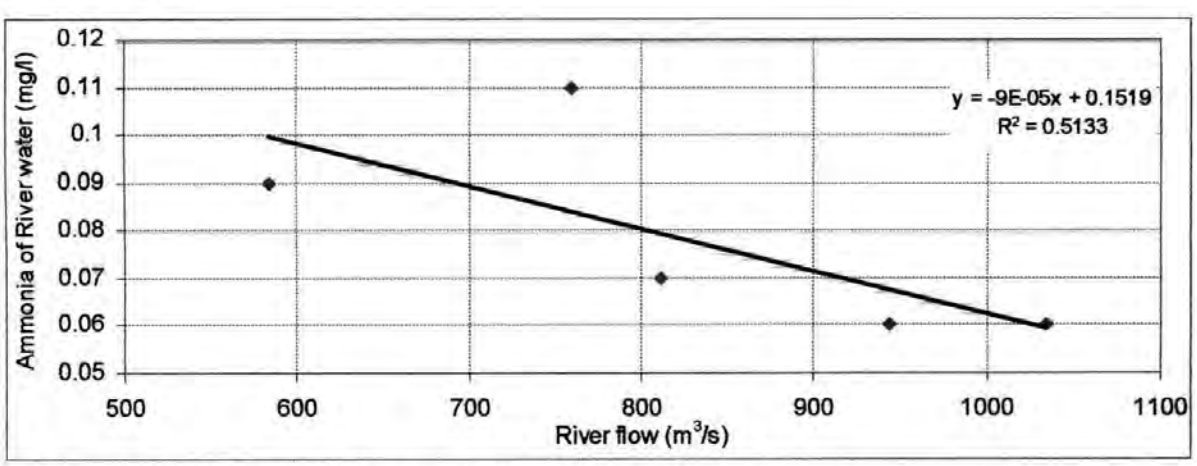


Figure 7.7: Relationship between River flow and Ammonia concentration at sampling point-9

7.5 Relationship between River flow and Concentration of Ammonium

Up stream (Sampling point-1)

The flow of Lakhya River at sampling point-1 varied 581.732-1032.429 m^3/s (824±155 m3/s) and the concentration of Ammonium varied 0.67-0.69 mg/l. From the figure 7.8 it is seen that the relationship between up stream river flow and concentration of Ammonium is inversely proportional. Monthly average concentration of Ammonium generated from this equation (Table A7.1).

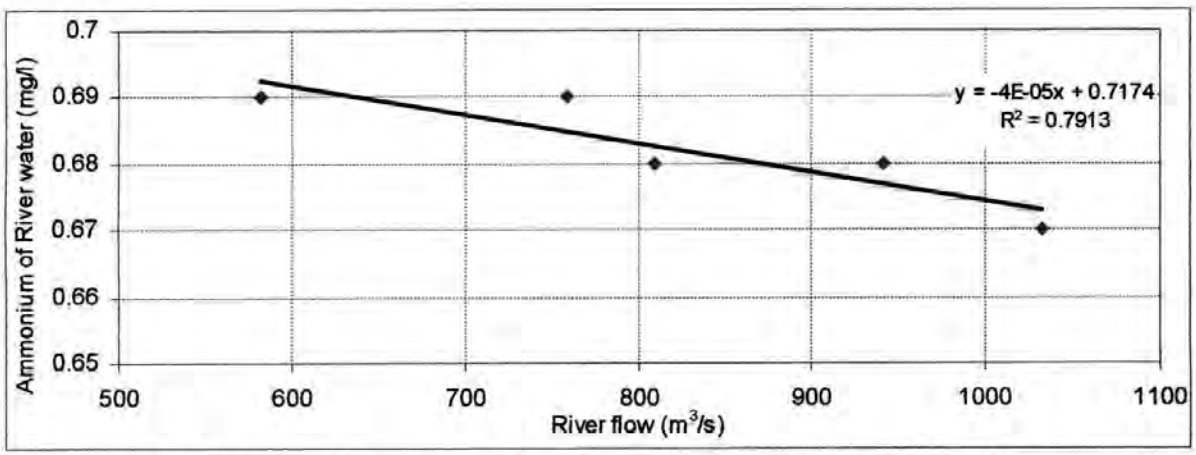


Figure 7.8: Relationship between River flow and Ammonium concentration at sampling point-1

Down stream (Sampling point-9)

The flow of Lakhya River at sampling point-9 varied 583.266-1034.22 m^3/s (826±155 m3/s) and the concentration of Ammonium varied 0.89-1.06 mg/l. From the figure 7.9, it is seen that the relationship between down stream river flow and concentration of Ammonium is inversely proportional. Monthly average concentration of Ammonium generated from this equation (Table A7.2).

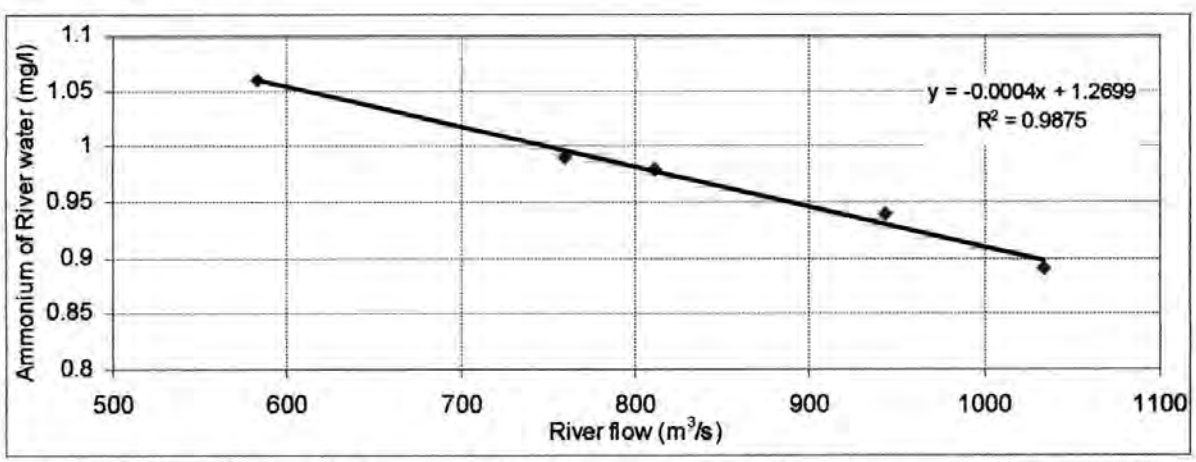


Figure 7.9: Relationship between River flow and Ammonium concentration at sampling point-9

7.6 Relationship between River flow and Concentration of BOD_5

Up stream (Sampling point-1)

The flow of Lakhya River at sampling point-1 varied 581.732-1032.429 m^3/s (824±155 m3/s) and the concentration of BOD_5 varied 8-11 mg/l. From the figure 7.10, it is seen that the relationship between up stream river flow and concentration of BOD_5 is inversely proportional. Monthly average concentration of BOD_5 generated from this equation (Table A7.1).

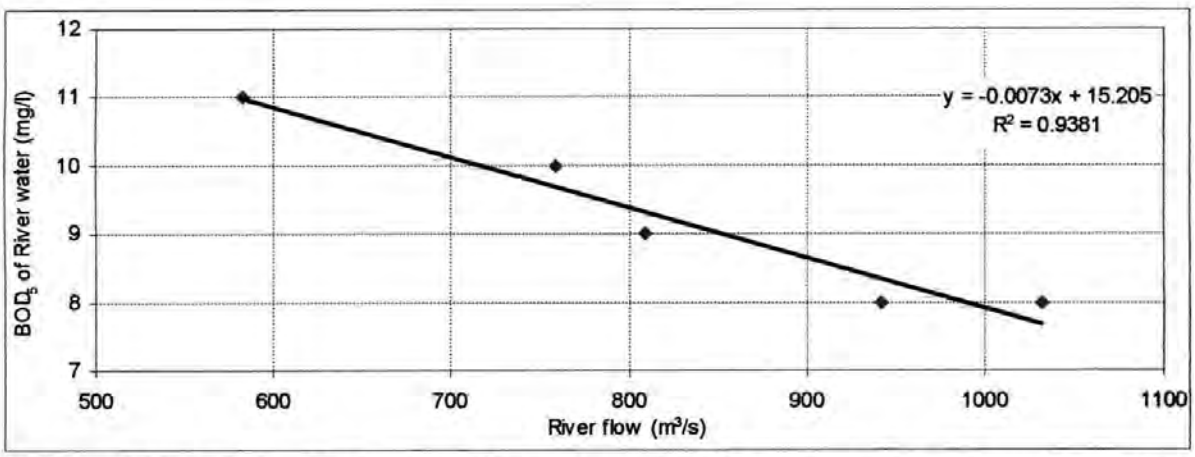


Figure 7.10: Relationship between River flow and BOD_5 concentration at sampling point-1

Down stream (Sampling point-9)

The flow of Lakhya River at sampling point-9 varied 583.266-1034.22 m^3/s (826±155 m3/s) and the concentration of BOD_5 varied 0.89-1.06 mg/l. From the figure 7.11, it is seen that the relationship between down stream river flow and concentration of Ammonium is inversely proportional. Monthly average concentration of BOD_5 generated from this equation (Table A7.2).

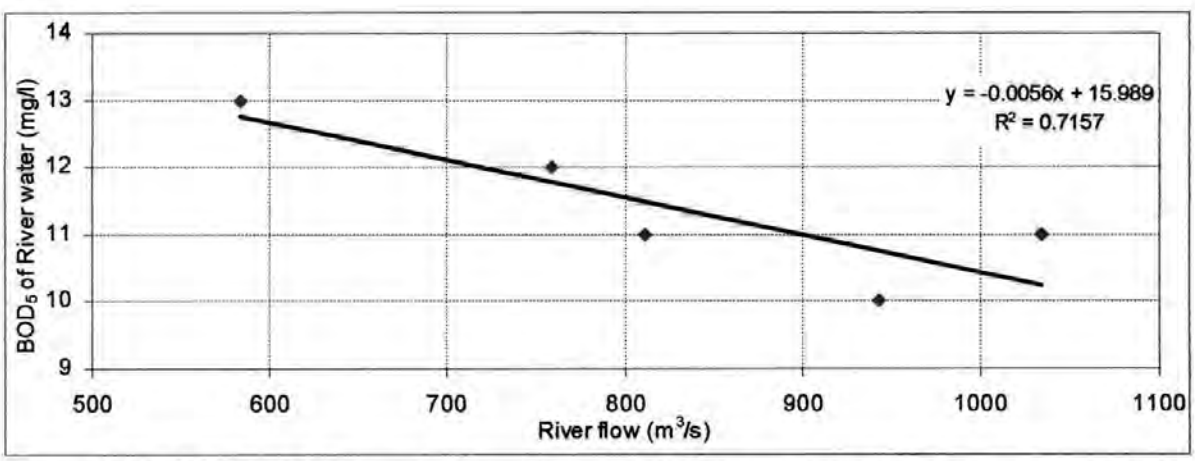


Figure 7.11: Relationship between River flow and BOD_5 concentration at sampling point-9

7.7 Relationship between River flow and Concentration of COD

Up stream (Sampling point-1)

The flow of Lakhya River at sampling point-1 varied 581.732-1032.429 m^3/s (824±155 m3/s) and the concentration of COD varied 12-19 mg/l. From the figure 7.12, it is seen that the relationship between up stream river flow and concentration of COD is inversely proportional. Monthly average concentration of COD generated from this equation (Table A7.1).

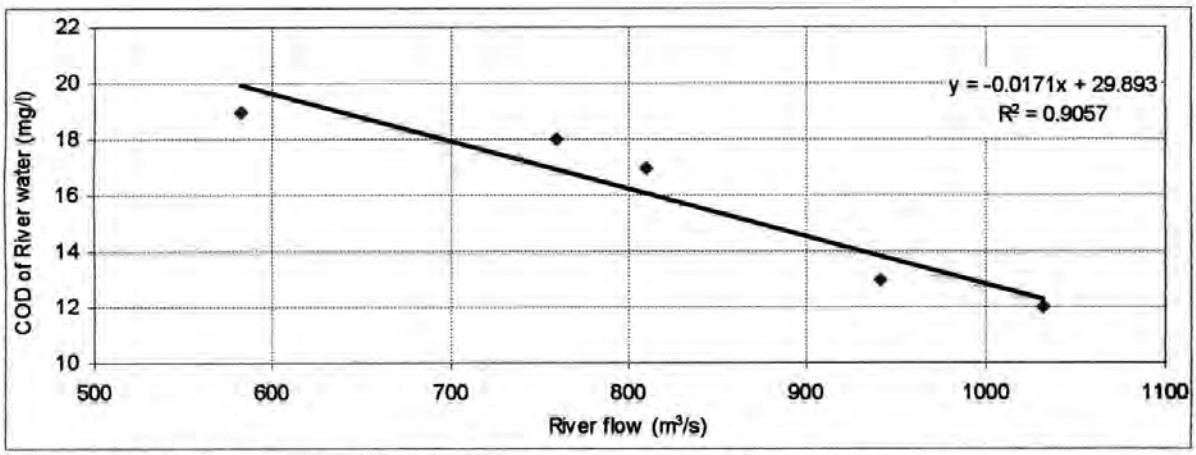


Figure 7.12: Relationship between River flow and COD concentration at sampling point-1

Down stream (Sampling point-9)

The flow of Lakhya River at sampling point-9 varied 583.266-1034.22 m^3/s (826±155 m3/s) and the concentration of COD varied 17-22 mg/l. From the figure 7.13, it is seen that the relationship between down stream river flow and concentration of COD is inversely proportional. Monthly average concentration of COD generated from this equation (Table A7.2).

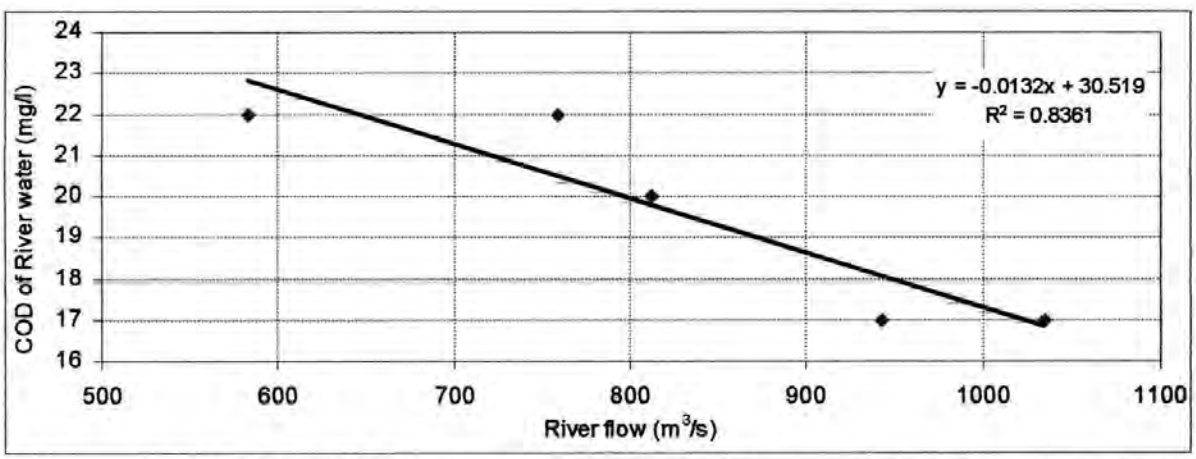


Figure 7.13: Relationship between River flow and COD concentration at sampling point-9

7.8 Relationship between River flow and Concentration of Total Solids

Up stream (Sampling point-1)

The flow of Lakhya River at sampling point-1 varied 581.732-1032.429 m^3/s (824±155 m3/s) and the concentration of TS varied 179-247 mg/l. From the figure 7.14, it is seen that the relationship between up stream river flow and concentration of TS is inversely proportional. Monthly average concentration of TS generated from this equation (Table A7.1).

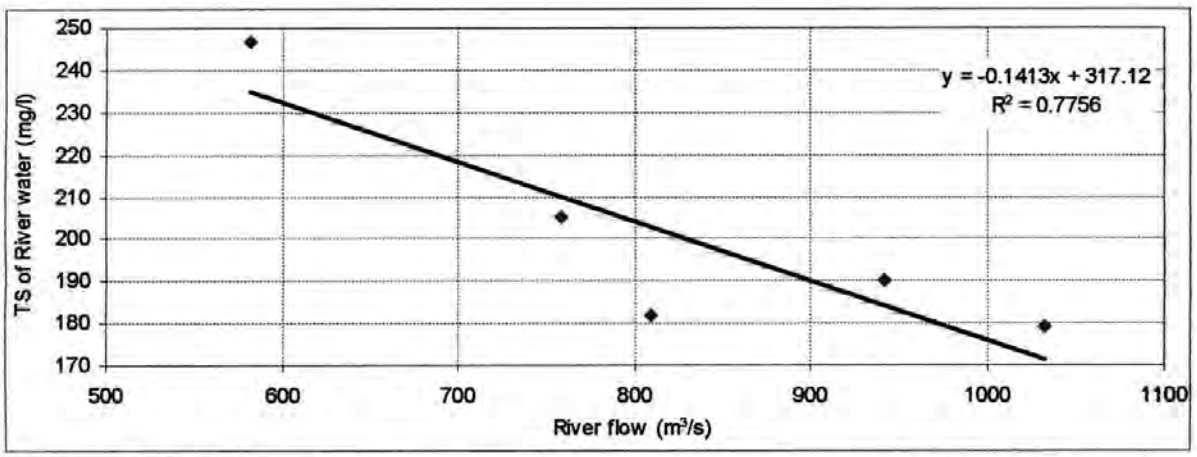


Figure 7.14: Relationship between River flow and TS concentration at sampling point-1

Down stream (Sampling point-9)

The flow of Lakhya River at sampling point-9 varied 583.266-1034.22 m^3/s (826±155 m3/s) and the concentration of TS varied 237-298 mg/l. From the figure 7.15, it is seen that the relationship between down stream river flow and concentration of TS is inversely proportional. Monthly average concentration of TS generated from this equation (Table A7.2).

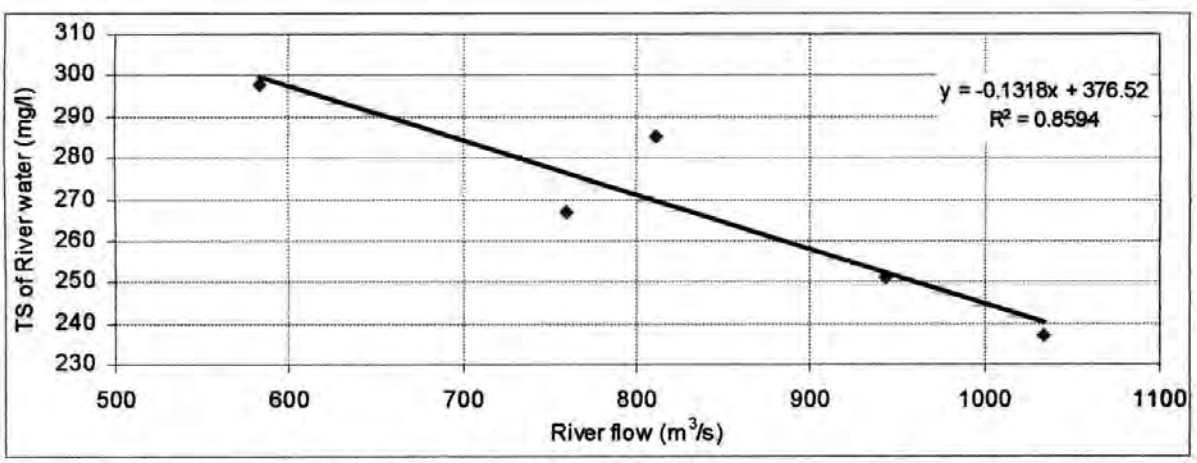


Figure 7.15: Relationship between River flow and TS concentration at sampling point-9

7.9 Relationship between River flow and Concentration of Total Dissolved Solids

Up stream (Sampling point-1)

The flow of Lakhya River at sampling point-1 varied 581.732-1032.429 m^3/s (824±155 m3/s) and the concentration of TDS varied 141-228 mg/l. From the figure 7.16, it is seen that the relationship between up stream river flow and concentration of TDS is inversely proportional. Monthly average concentration of TDS generated from this equation (Table A7.1).

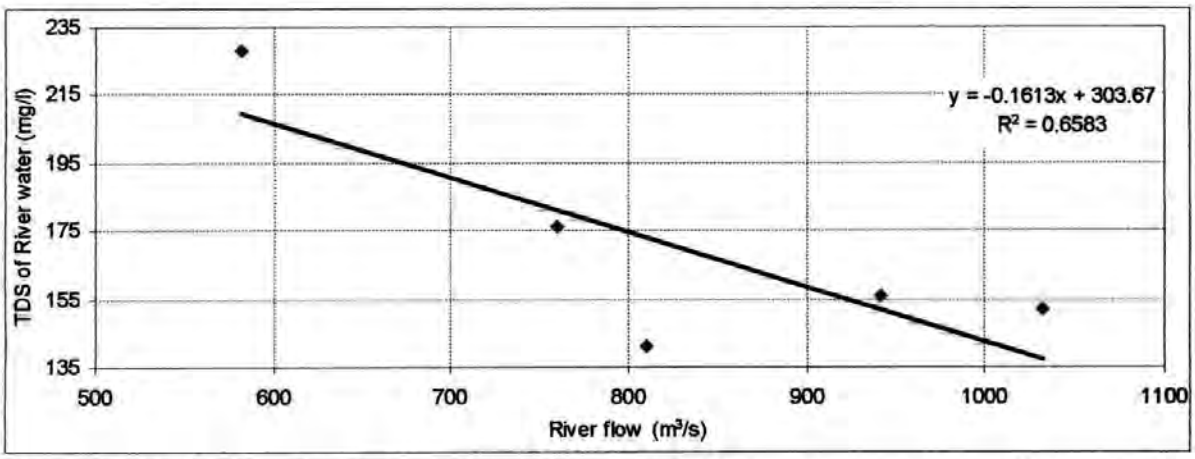


Figure 7.16: Relationship between River flow and TDS concentration at sampling point-1

Down stream (Sampling point-9)

The flow of Lakhya River at sampling point-9 varied 583.266-1034.22 m^3/s (826±155 m3/s) and the concentration of TDS varied 192-271 mg/l. From the figure 7.17, it is seen that the relationship between down stream river flow and concentration of TDS is inversely proportional. Monthly average concentration of TDS generated from this equation (Table A7.2).

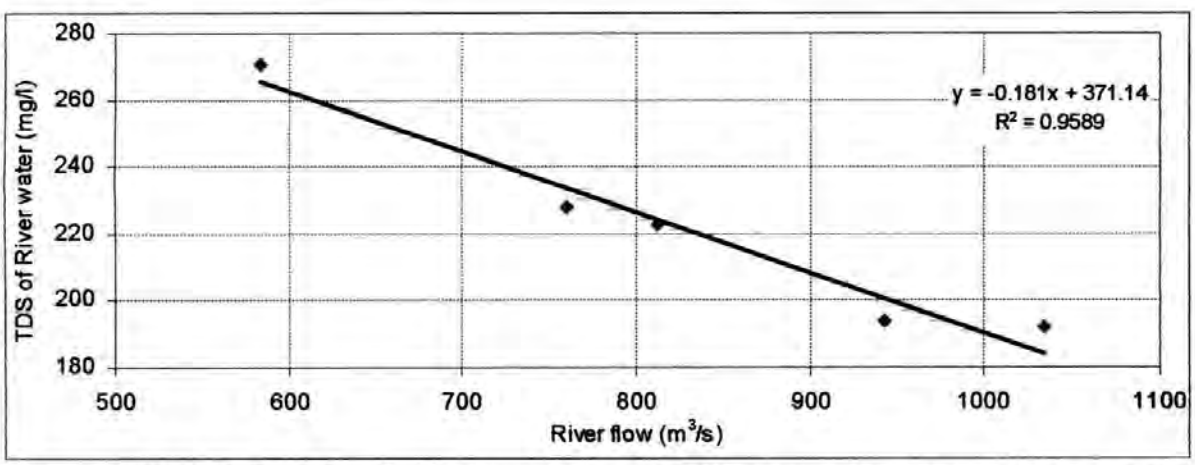


Figure 7.17: Relationship between River flow and TDS concentration at sampling point-9

7.10 Comparision of Correlation co-efficient of Different Water Quality Parameters

Location	Sampling point	Water Quality Parameters						
		Total NH_3-N	NH_3-N	NH_4-N	BOD_5	COD	TS	TDS
Up stream	1	0.90	0.73	0.79	0.94	0.90	0.78	0.66
Down stream	9	0.97	0.51	0.98	0.72	0.84	0.86	0.96

From the above comparision it is noted that generated equation best suited in the up stream for Total Ammonia, Ammonia, Biochemical Oxygen Demand (BOD), and Chemical Oxygen Demand and in the down stream for Ammonium, Total Solids, and Total Dissolved Solids.

7.11 Comparision between up stream and down stream water quality parameters

7.11.1 Total Ammonia (NH_3-N)

The Total Ammonia concentration varied 0.67-0.75 mg/l in sampling point-1 and 0.87-1.42 mg/l in sampling point-9. Maximum concentration occurred in February (0.75 mg/l in point-1 and 1.42 mg/l in point-9) and minimum in August (0.67 mg/l in point-1 and 0.87 mg/l). The maximum impact occurred in February where the increase of Total Ammonia concentration is 0.67 mg/l and the minimum in August where the increase of Ammonia concentration is 0.21 mg/l. The comparision of Total Ammonia concentration between up stream (sampling point-1) and down stream (sampling point-9) are shown in Figure 7.18 and 7.19

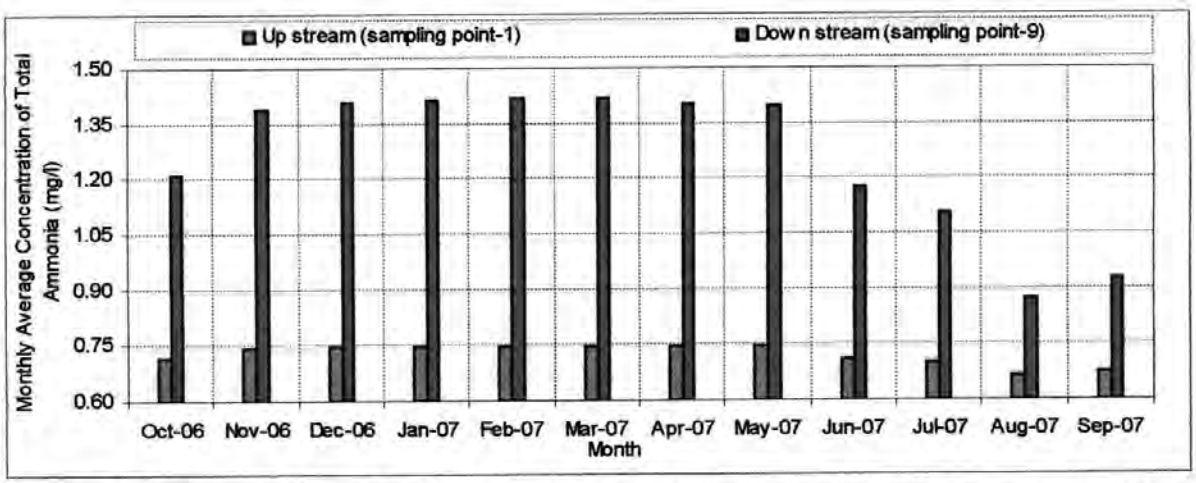


Figure 7.18: Comparision of Total Ammonia concentration (simulated) between up stream and down stream

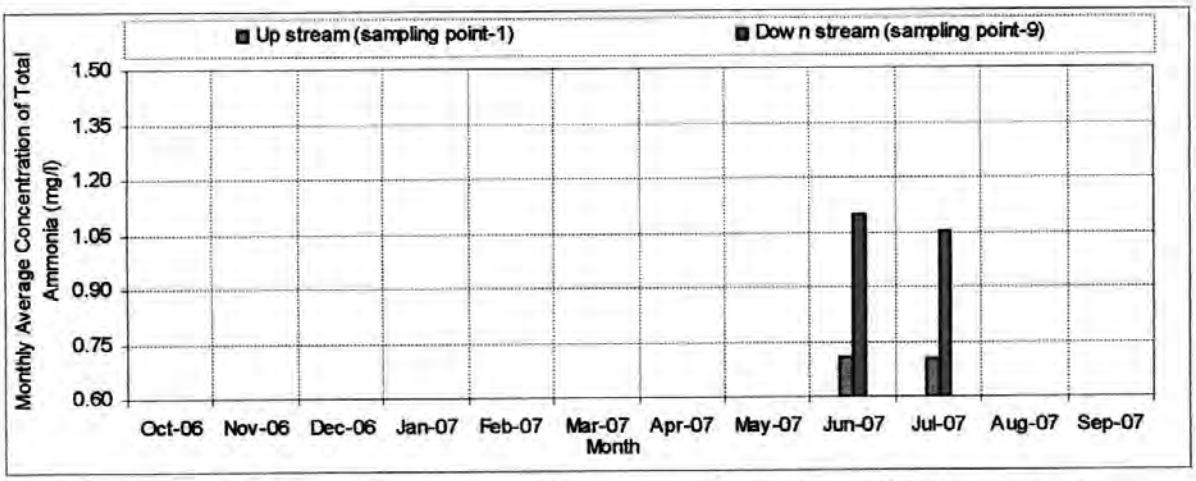


Figure 7.19: Comparision of Total Ammonia concentration (observed) between up stream and down stream

7.11.2 Ammonia (NH_3-N)

The Ammonia concentration varied 0-0.04 mg/l in sampling point-1 and 0.03-0.15 mg/l in sampling point-9. Maximum concentration occurred in February (0.04 mg/l in point-1 and 0.15 mg/l in point-9) and minimum in August (0 mg/l in point-1 and 0.03 mg/l in point-9). The maximum impact occurred in February where the increase of Ammonia concentration is 0.11 mg/l and the minimum in August where the increase of Ammonia concentration is 0.03 mg/l. The comparision of Ammonia concentration between up stream (sampling point-1) and down stream (sampling point-9) are shown in Figure 7.20 and 7.21

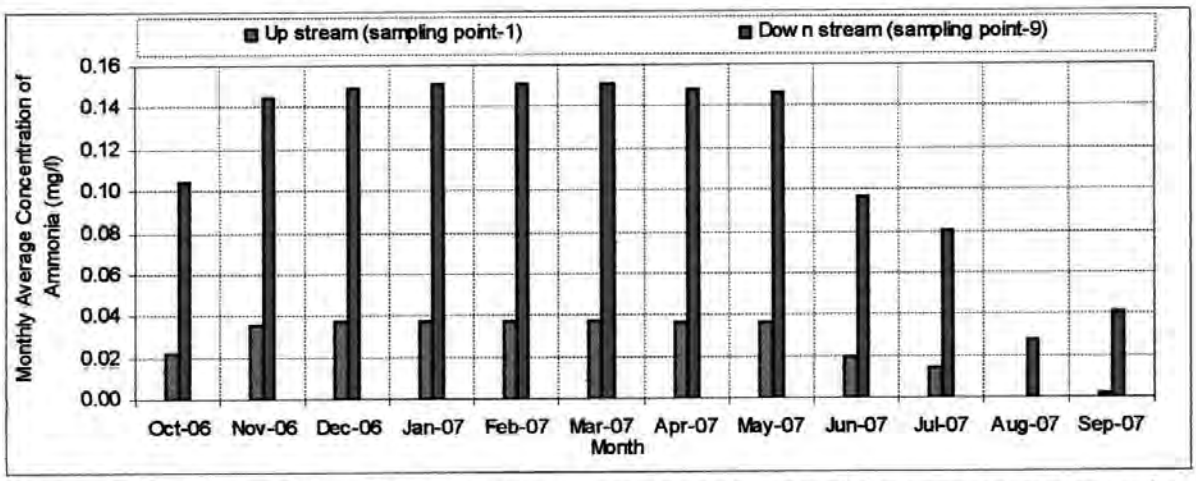


Figure 7.20: Comparision of Ammonia concentration (simulated) between up stream and down stream

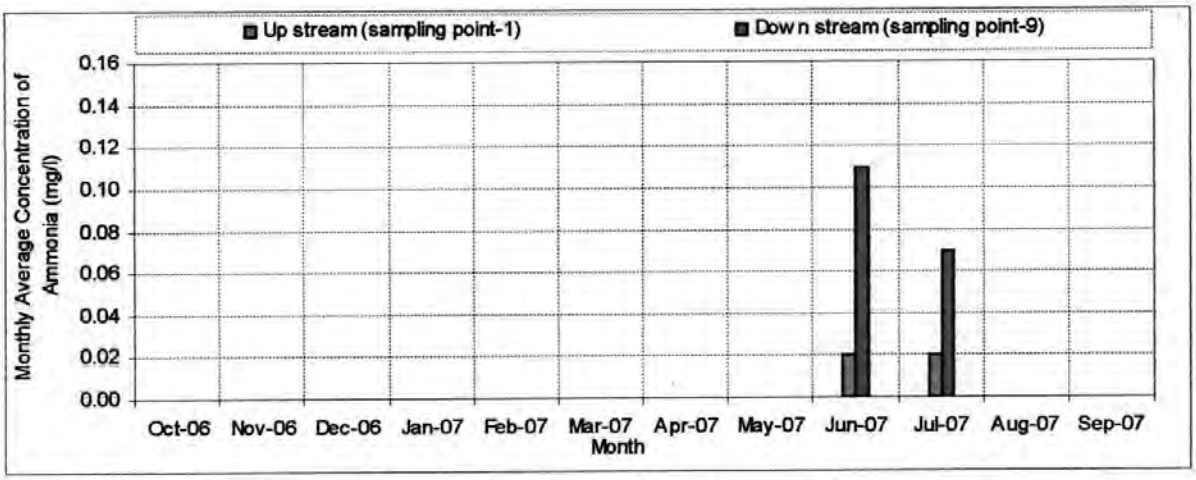


Figure 7.21: Comparision of Ammonia concentration (observed) between up stream and down stream

7.11.3 Ammonium (NH_4-N)

The Ammonium concentration varied 0.66-0.72 mg/l in sampling point-1 and 0.72-1.27 mg/l in sampling point-9. Maximum concentration occurred in February (0.72 mg/l in point-1 and 1.27 mg/l in point-9) and minimum in August (0.66 mg/l in point-1 and 0.72 mg/l in point-9). The maximum impact occurred in February where the increase of Ammonium concentration is 0.55 mg/l and the minimum in August where the increase of Ammonium concentration is 0.06 mg/l. The comparision of Ammonium concentration between up stream (sampling point-1) and down stream (sampling point-9) are shown in Figure 7.21 and 7.22

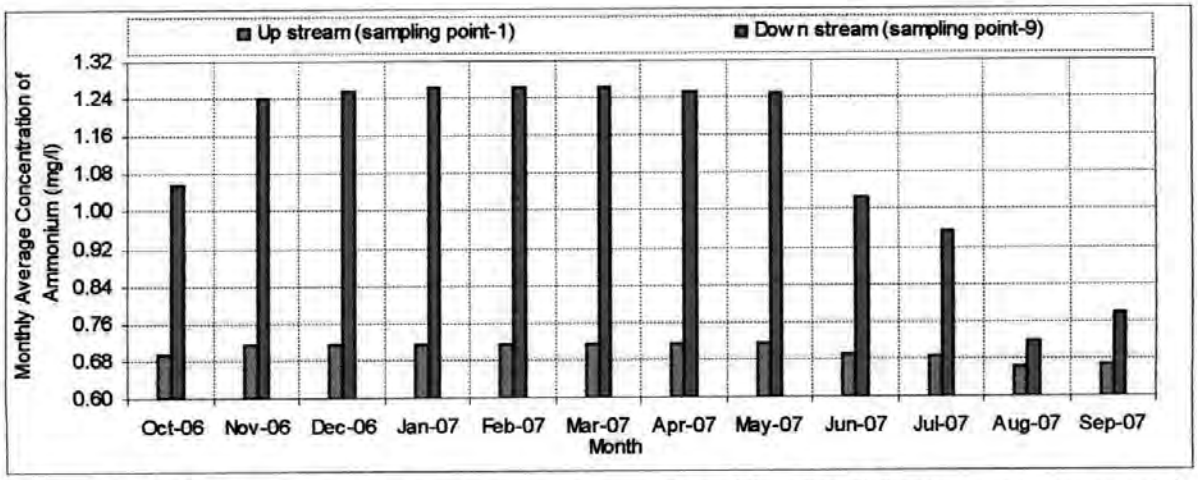


Figure 7.21: Comparision of Ammonium concentration (simulated) between up stream and down stream

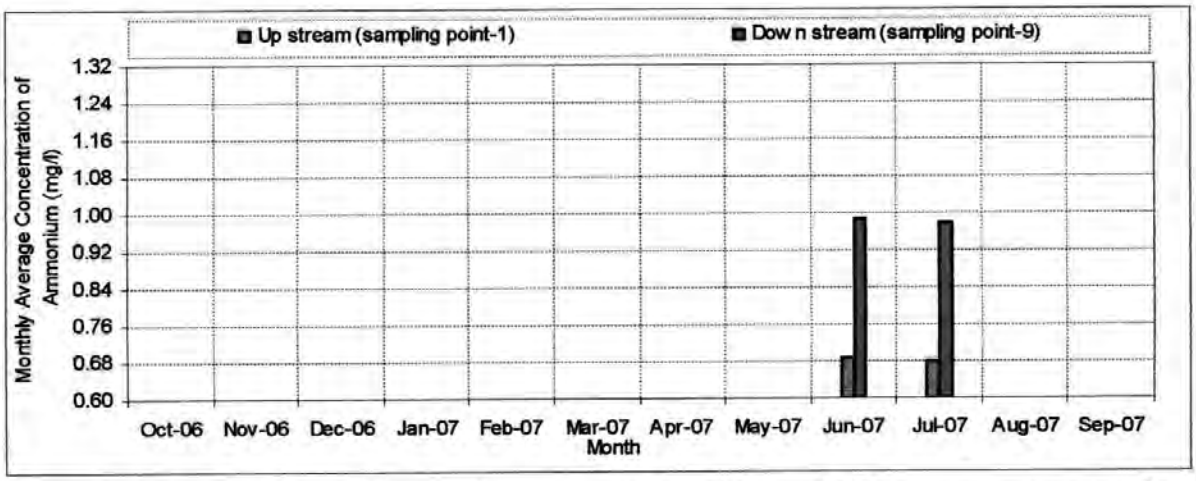


Figure 7.22: Comparision of Ammonium concentration (observed) between up stream and down stream

7.11.4 Bio-chemical Oxygen Demand (BOD)

The BOD_5 concentration varied 5.19-15.13 mg/l in sampling point-1 and 8.29-15.93 mg/l in sampling point-9. Maximum concentration occurred in February (15.13 mg/l in point-1 and 15.93 mg/l in point-9) and minimum in August (5.19 mg/l in point-1 and 8.29 mg/l in point-9). The maximum impact occurred in August where the increase of BOD_5 concentration is 3.10 mg/l and the minimum in February where the increase of BOD_5 concentration is 0.80 mg/l. The comparision of BOD_5 concentration between up stream (sampling point-1) and down stream (sampling point-9) are shown in Figure 7.23 and 7.24

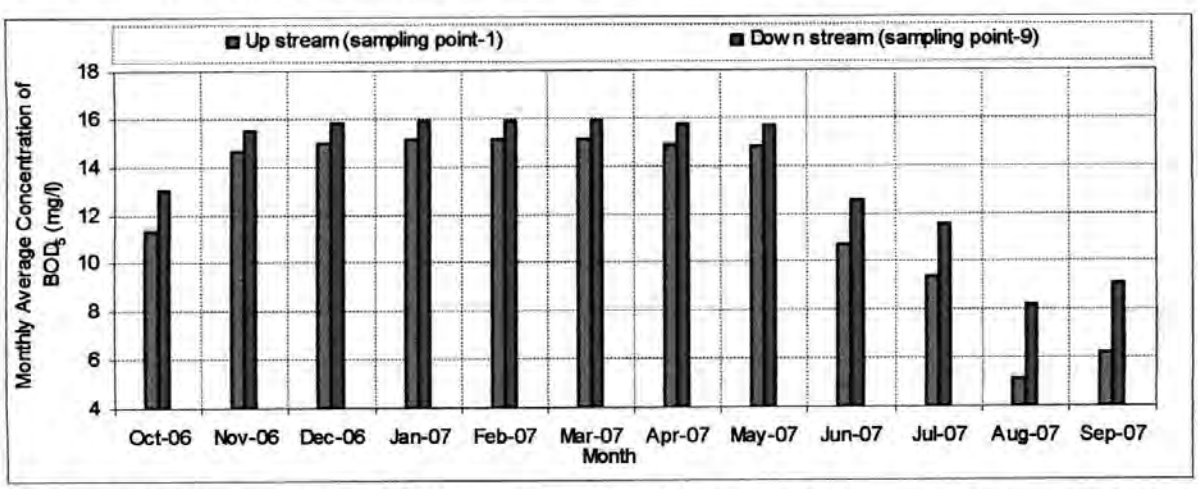


Figure 7.23: Comparision of BOD_5 concentration (simulated) between up stream and down stream

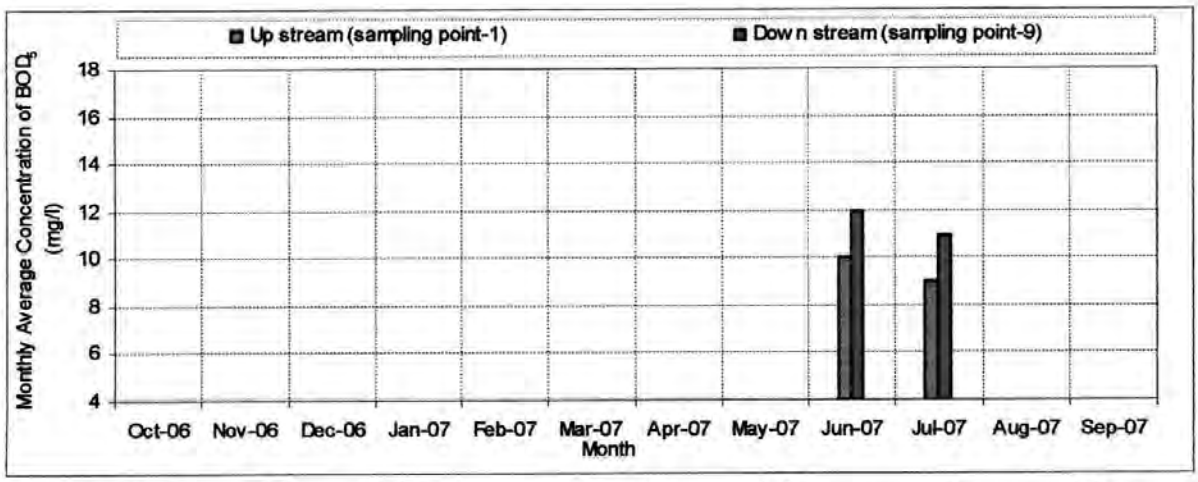


Figure 7.24: Comparision of BOD_5 concentration (observed) between up stream and down stream

7.11.5 Chemical Oxygen Demand (COD)

The COD concentration varied 6.43-29.71 mg/l in sampling point-1 and 12.36-30.38 mg/l in sampling point-9. Maximum concentration occurred in February (29.71 mg/l in point-1 and 30.38 mg/l in point-9) and minimum in August (6.43 mg/l in point-1 and 12.36 mg/l in point-9). The maximum impact occurred in August where the increase of COD concentration is 5.93 mg/l and the minimum in February where the increase of COD concentration is 0.67 mg/l. The comparision of COD concentration between up stream (sampling point-1) and down stream (sampling point-9) are shown in Figure 7.25 and 7.26

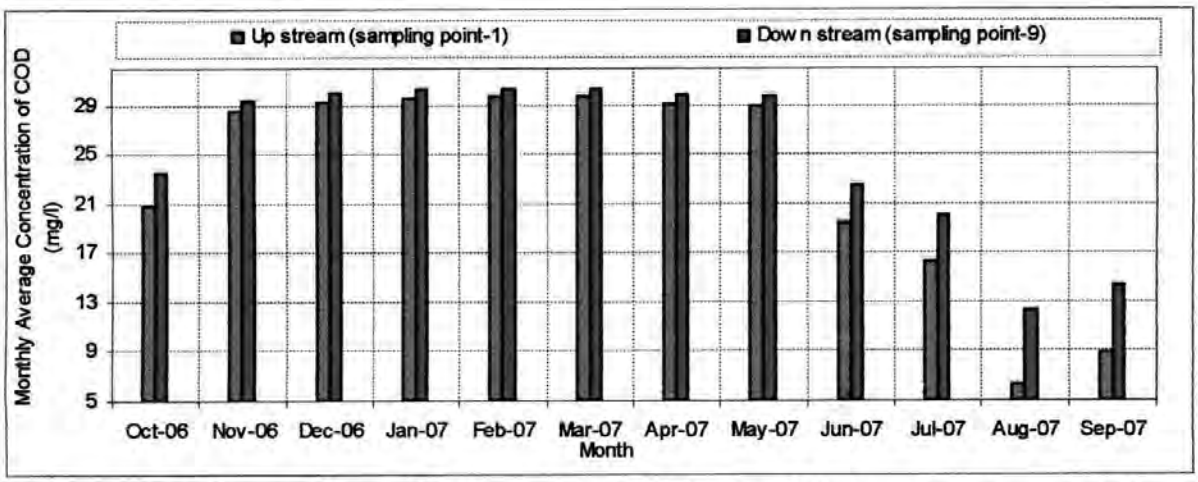


Figure 7.25: Comparision of COD concentration (simulated) between up stream and down stream

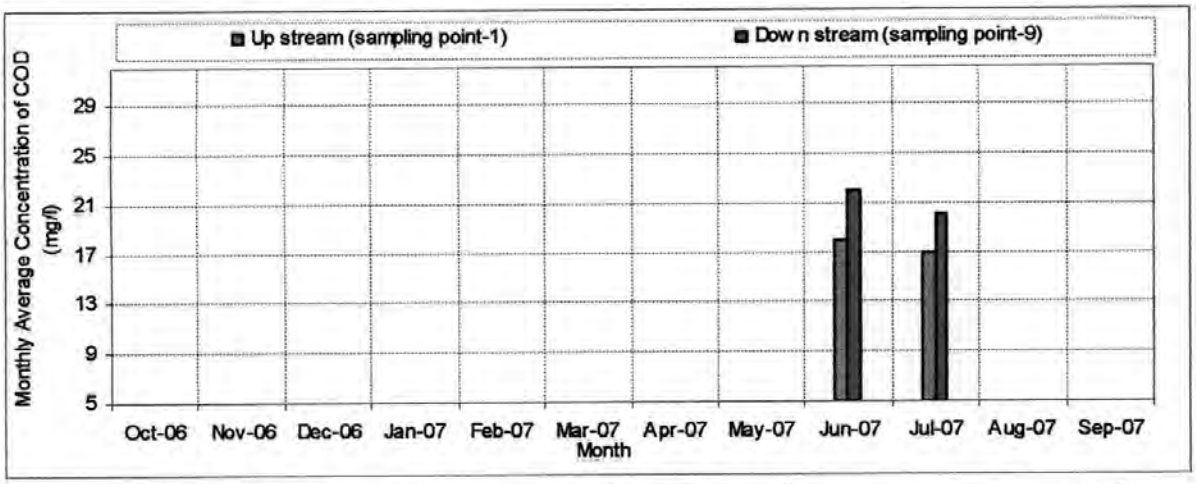


Figure 7.26: Comparision of COD concentration (observed) between up stream and down stream

7.11.6 Total Solids (TS)

The TS concentration varied 123.25-315.58 mg/l in sampling point-1 and 195.21-375.09 mg/l in sampling point-9. Maximum concentration occurred in February (315.58 mg/l in point-1 and 375.09 mg/l in point-9) and minimum in August (123.25 mg/l in point-1 and 195.21 mg/l in point-9). The maximum impact occurred in August where the increase of TS concentration is 71.97 mg/l and the minimum in February where the increase of TS concentration is 59.50 mg/l. The comparision of TS concentration between up stream (sampling point-1) and down stream (sampling point-9) are shown in Figure 7.27 and 7.28

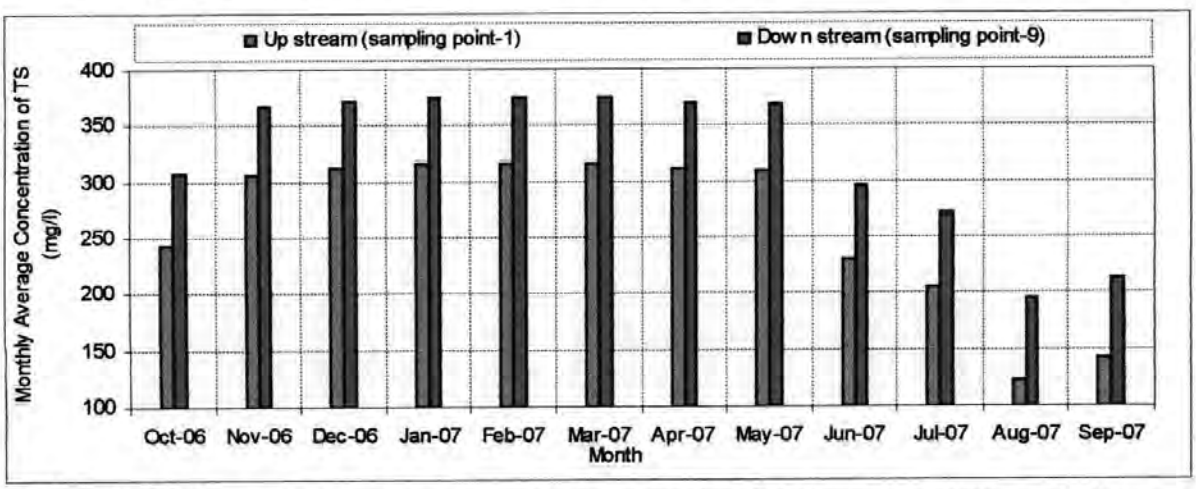


Figure 7.27: Comparision of TS concentration (simulated) between up stream and down stream

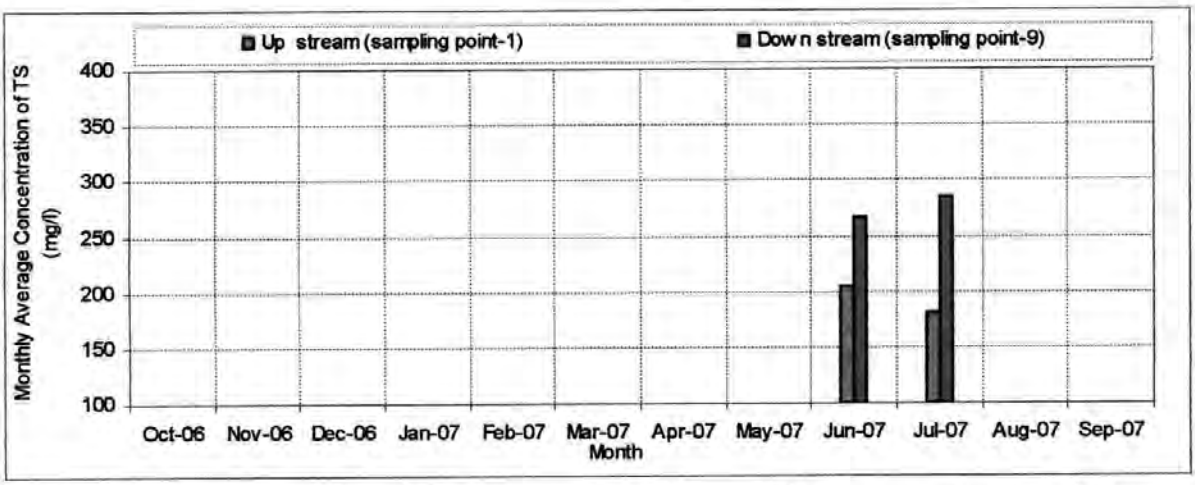


Figure 7.28: Comparision of TS concentration (observed) between up stream and down stream

7.11.7 Total Dissolved Solids (TDS)

The TDS concentration varied 82.35-301.91 mg/l in sampling point-1 and 122.15-369.17 mg/l in sampling point-9. Maximum concentration occurred in February (301.91 mg/l in point-1 and 369.17 mg/l in point-9) and minimum in August (82.35 mg/l in point-1 and 122.15 mg/l in point-9). The maximum impact occurred in February where the increase of TS concentration is 67.26 mg/l and the minimum in August where the increase of TDS concentration is 39.80 mg/l. The comparision of TDS concentration between up stream (sampling point-1) and down stream (sampling point-9) are shown in Figure 7.29 and 7.30

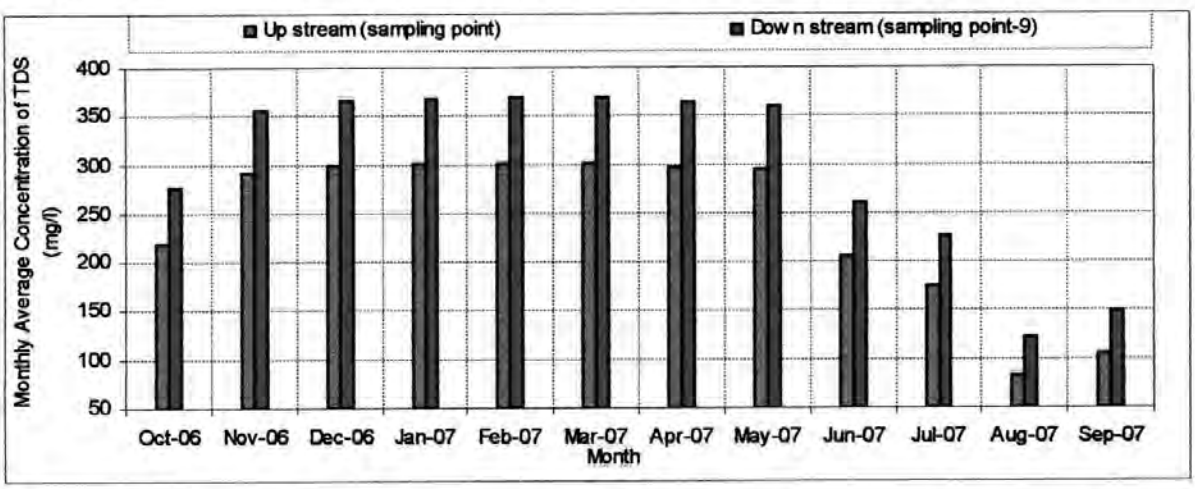


Figure 7.29: Comparision of TDS concentration (simulated) between up stream and down stream

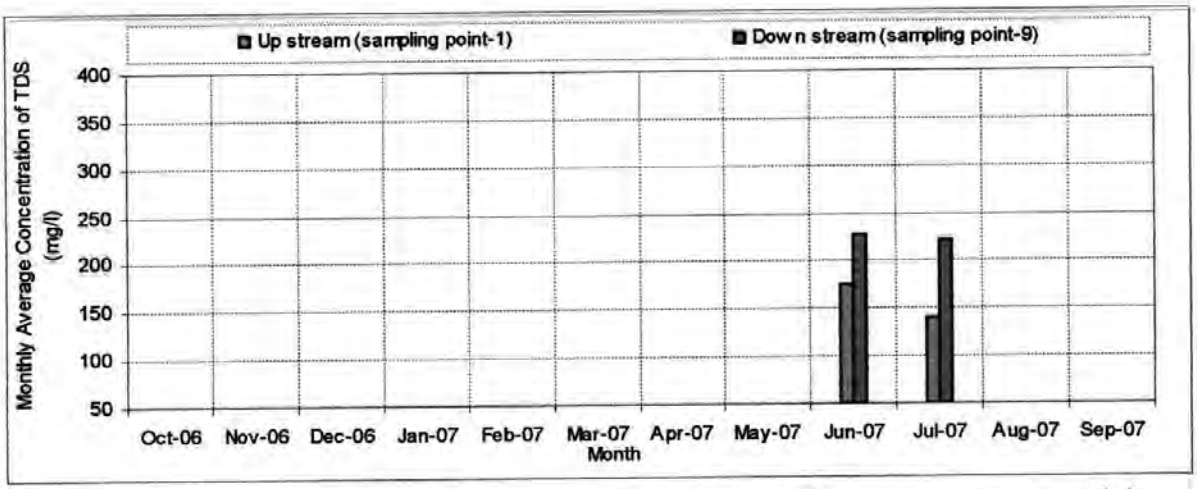


Figure 7.30: Comparision of TDS concentration (observed) between up stream and down stream

7.12 Relationship between Temperature and Dissolved Oxygen along the Lakhya River

Oxygen is both added and removed from water. Water gains oxygen from the atmosphere and from plants as a result of photosynthesis. In addition, the churning of running water helps add dissolved oxygen. Respiration (breathing) by aquatic animals, decomposition, and various chemical reactions, consume oxygen from the water body. If more oxygen is consumed than is produced, dissolved oxygen levels decline and some sensitive animals may move away, weaken or die. Dossolved oxygen levels vary with water temperature, altitude, depth, daily and seasonal cycles and discharge. For example, water at high altitudes holds less oxygen due to lower atmospheric pressure. Warm water holds less oxygen than cold water. Dissolved oxygen levels change with the seasons as the temperature of the changes. Relationship between temperature and Dissolved Oxygen are shown in Figure 7.31

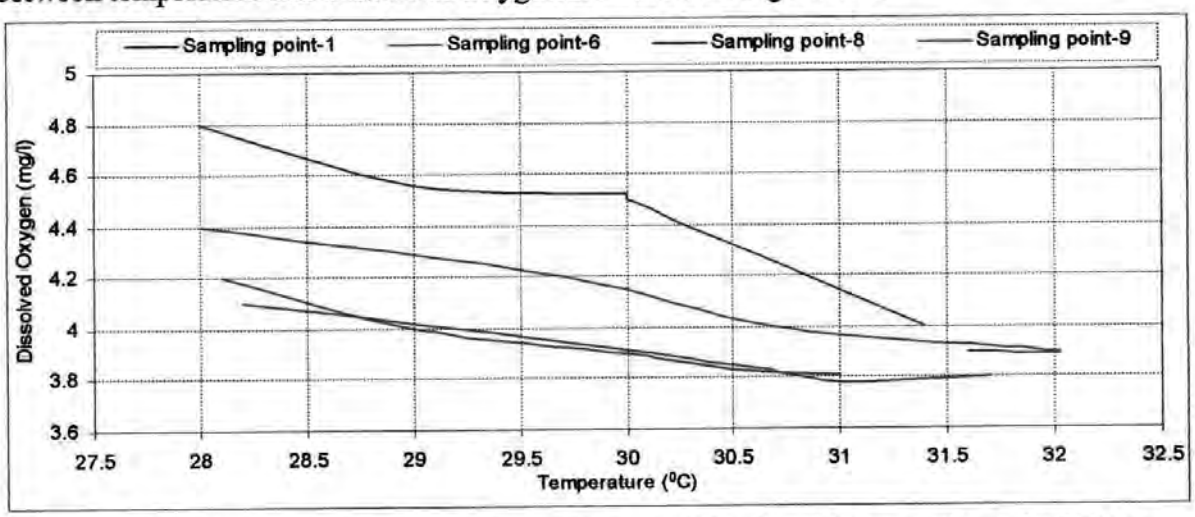


Figure 7.31: Relationship between Temperature and Dissolved Oxygen along the Lakhya River

7.13 Percent Saturation of Dissolved Oxygen along the Lakhya River

The percent saturation of Dissolved Oxygen was 54-60 % (57.8±2.039 %) in the sampling point-1. In the sampling point-6 it was 52.5-56 % (54.3±1.16 %) due to pollution load discharged from sampling point-5. In the sampling point-8 it was 50-53 % (51.8±0.98 %) due to pollution load discharged from sampling point-4 and 7. For the dilution factor the pollution load reduced in the sampling point-9, the percent saturation of DO increase in that point and it was 52-54 % (52.9±0.73 %). The percent saturation of Dissolved Oxygen along the Lakhya River are shown in Figure 7.32 and Table A7.4

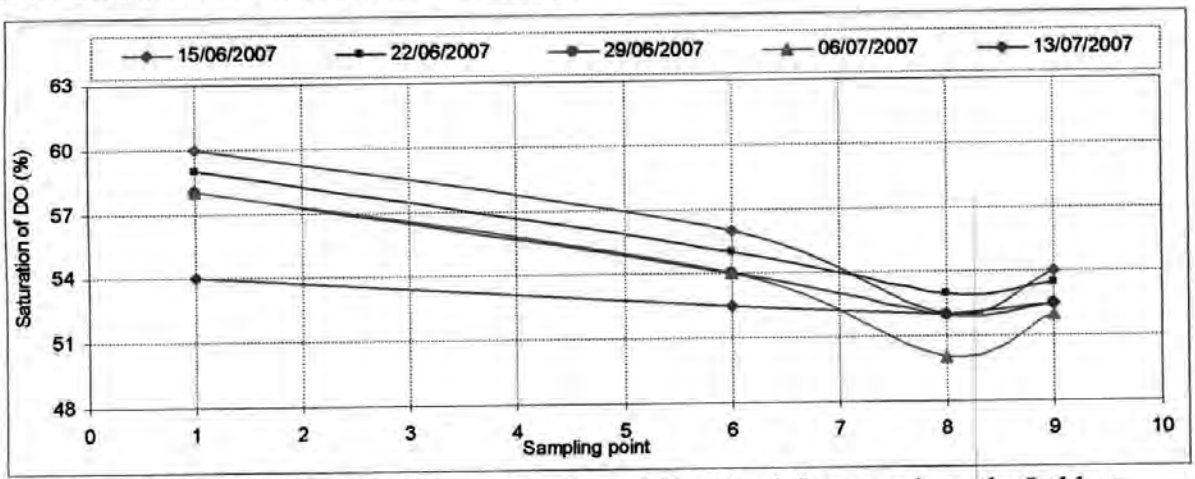


Figure 7.32: Variation of percent saturation of Dissolved Oxygen along the Lakhya River

7.13 Development of Industrial Policy from Impact of Effluent

7.13.1 Ammonia

Minimum impact of effluent occurred in August where Ammonia load discharged from industry is 0.23 times of upstream load of Ammonia. On the other hand maximum impact occurred in February where Ammonia load discharged from industry in 25.86 times of upstream load of Ammonia. From this analysis it is easy to determine the load of Ammonia at the down stream. From the expected load at the downstream the authority could formulate the policy 1) to permit the maximum load of Ammonia discharged from industry 2) The number of industry will permit for sustainable developement in respect of Ammonia

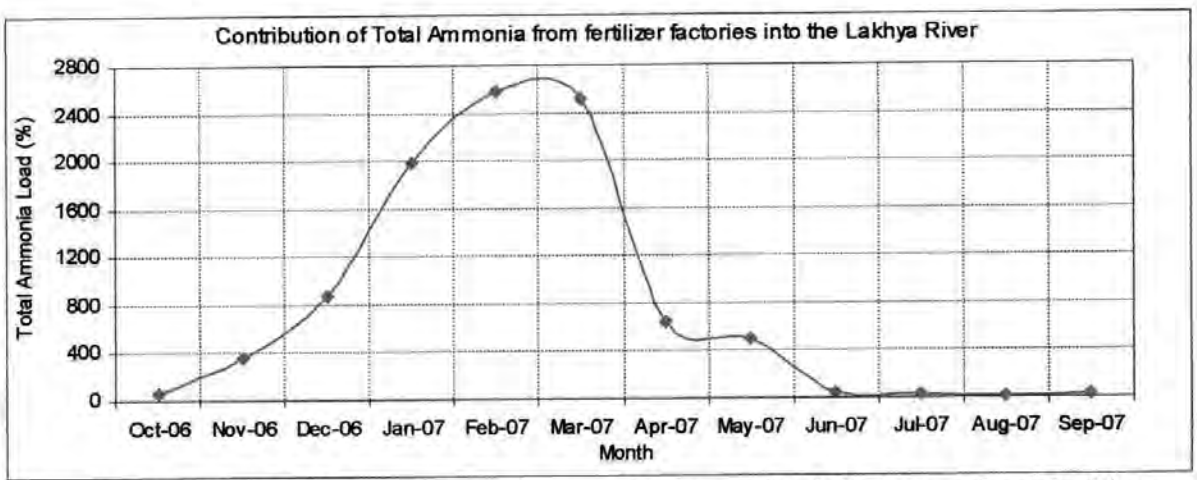


Figure 7.33: The load of Ammonia as percent of upstream load discharged from fertilizer factories into the Lakhya River

7.13.2 Ammonium

Minimum impact of effluent occurred in August where Ammonium load discharged from industry is 0.11 times of upstream load of Ammonium. On the other hand maximum impact occurred in February where Ammonium load discharged from industry in 13.35 times of upstream load of Ammonium. From this analysis it is easy to determine the load of Ammonium at the down stream. From the expected load at the downstream the authority could formulate the policy 1) to permit the maximum load of Ammonium discharged from industry 2) The number of industry will permit for sustainable developement in respect of Ammonium

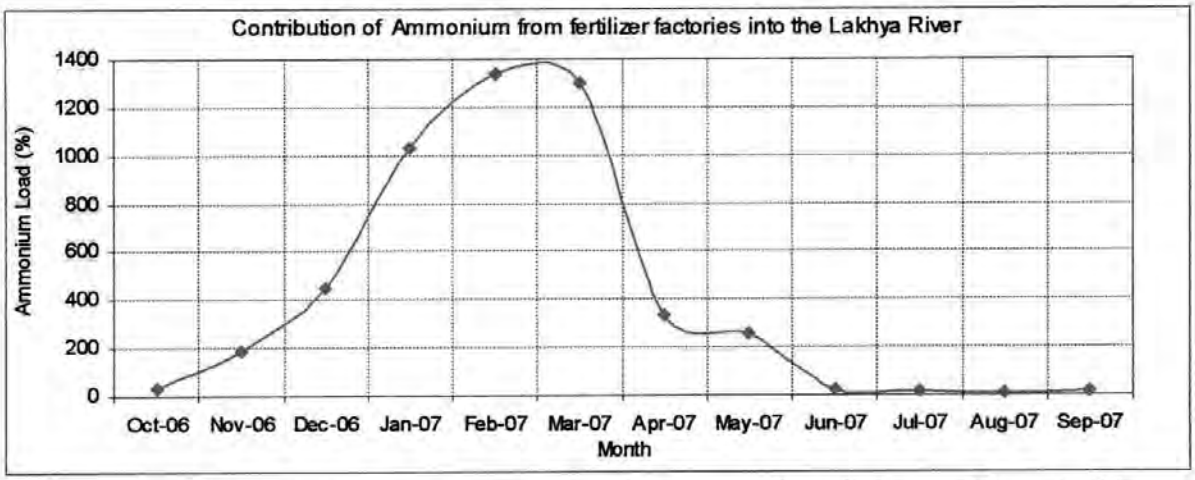


Figure 7.34: The load of Ammonia as percent of upstream load discharged from fertilizer factories into the Lakhya River

7.13.2 Biochemical Oxygen Demand (BOD)

Minimum impact of effluent occurred in September where BOD_5 load discharged from industry is 0.0047 times of upstream load of BOD_5. On the other hand maximum impact occurred in February where BOD_5 load discharged from industry is 0.22 times of upstream load of BOD_5. From this analysis it is easy to determine the load of BOD_5 at the down stream. From the expected load at the downstream the authority could formulate the policy 1) to permit the maximum load of BOD_5 discharged from industry 2) The number of industry will permit for sustainable developement in respect of BOD_5

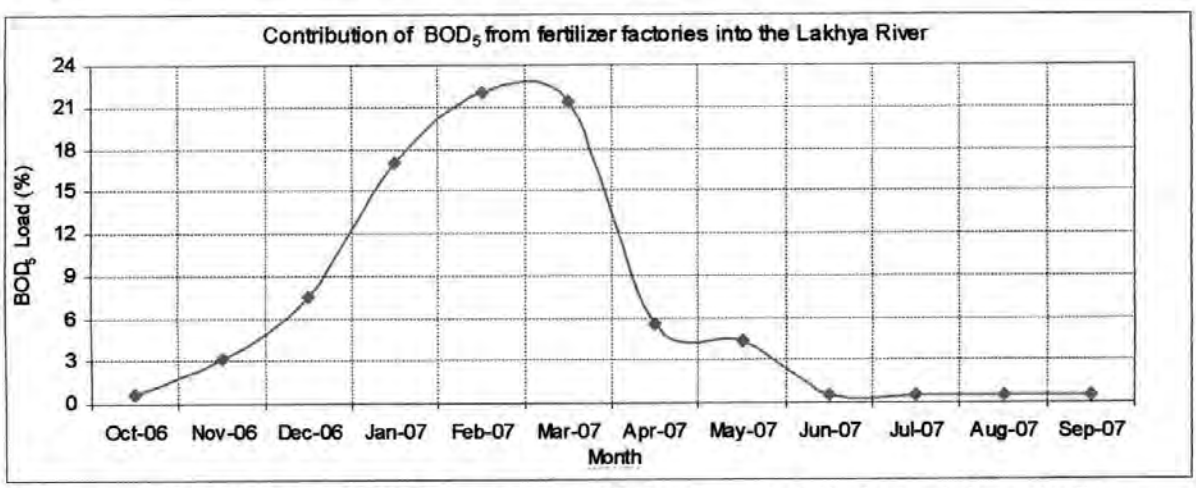


Figure 7.35: The load of BOD_5 as percent of upstream load discharged from fertilizer factories into the Lakhya River

7.13.3 Chemical Oxygen Demand (COD)

Minimum impact of effluent occurred in July where COD load discharged from industry is 0.0044 times of upstream load of COD. On the other hand maximum impact occurred in February where COD load discharged from industry is 0.18 times of upstream load of COD. From this analysis it is easy to determine the load of COD at the down stream. From the expected load at the downstream the authority could formulate the policy 1) to permit the maximum load of COD discharged from industry 2) The number of industry will permit for sustainable developement in respect of COD

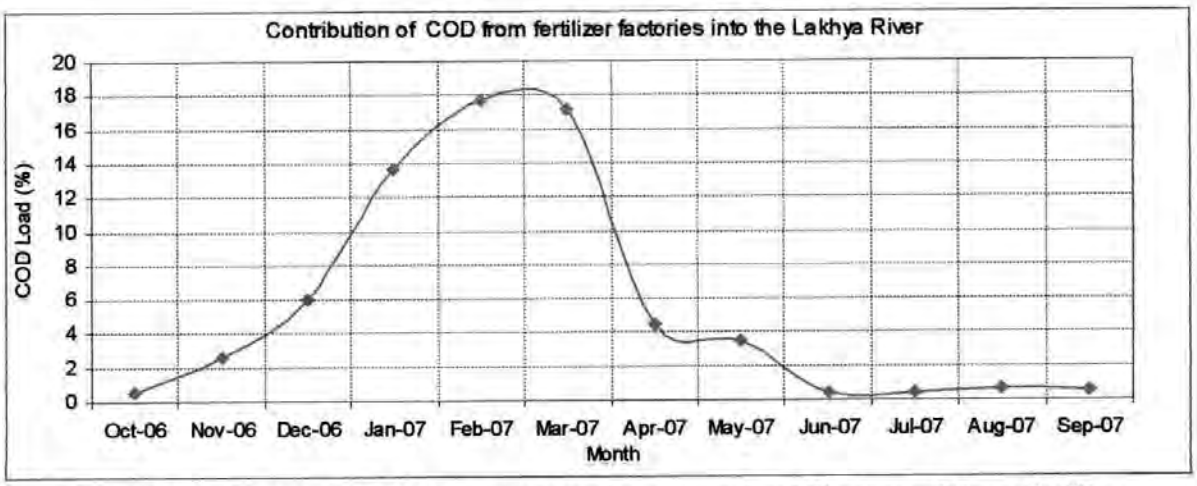


Figure 7.36: The load of COD as percent of upstream load discharged from fertilizer factories into the Lakhya River

7.13.4 Total Solids (TS)

Minimum impact of effluent occurred in September where load of Total Solids discharged from industry is 0.00057 times of upstream load of Total Solids. On the other hand maximum impact occurred in February where load of total solids discharged from industry is 0.029 times of upstream load of total solids. From this analysis it is easy to determine the load of total solids at the down stream. From the expected load at the downstream the authority could formulate the policy 1) to permit the maximum load of total solids discharged from industry 2) The number of industry will permit for sustainable developement in respect of total solids

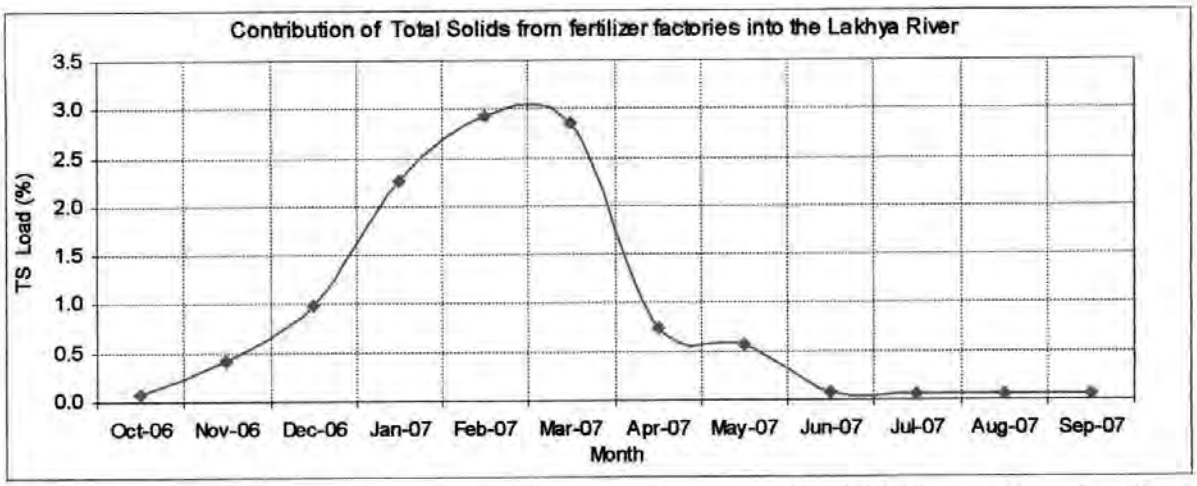


Figure 7.37: The load of Total solids as percent of upstream load discharged from fertilizer factories into the Lakhya River

7.13.5 Total Dissolved Solids

Minimum impact of effluent occurred in May where load of Total Dissolved Solids discharged from industry is 0.0032 times of upstream load of Total Dissolved Solids. On the other hand maximum impact occurred in February where load of total dissolved solids discharged from industry is 0.022 times of upstream load of total dissolved solids. From this analysis it is easy to determine the load of total dissolved solids at the down stream. From the expected load at the downstream the authority could formulate the policy 1) to permit the maximum load of total dissolved solids discharged from industry 2) The number of industry will permit for sustainable developement in respect of total dissolved solids

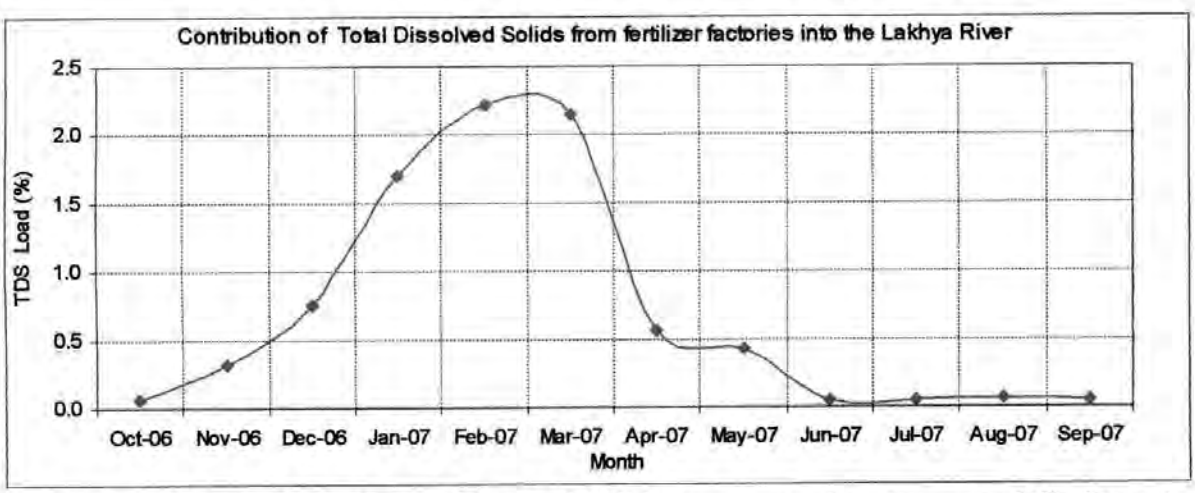


Figure 7.38: The load of Total Dissolved Solids as percent of upstream load discharged from fertilizer factories into the Lakhya River

CHAPTER 8

CONCLUSION AND RECOMMENDATIONS

8.1 Conclusion

The main focus of this study was Characterization of effluent from fertilizer factories, Estimation of water pollution load discharged from fertilizer factories, Analysis of water quality along the Lakhya River to assess impact of fertilizer factories effluent, Recommending interventions to minimize impact

Following are the major findings from this study: The values of effluent parameters shows in range.

- The levels of Biochemical Oxygen Demand (BOD) were 43-60 mg/l, 24-46 mg/l, 120-148 mg/l, 21-31 mg/l, 19-53 mg/l in the effluent from sampling point-2, 3, 4, 5 and 7 respectively. The levels of Chemical Oxygen Demand (COD) were 78-86 mg/l, 43-69 mg/l, 198-234 mg/l, 37-53 mg/l, and 52-64 mg/l in the effluent from sampling point-2, 3, 4, 5 and 7 respectively. The levels of Dissolved Oxygen (DO) were 0.65-0.78 mg/l, 2.86-2.96 mg/l, 2.81-2.91 mg/l, 2.64-2.89 mg/l, and 2.8-3 mg/l in the effluent from sampling point-2, 3, 4, 5 and 7 respectively. The levels of pH were 8.4-8.9 mg/l, 8.2-8.5 mg/l, 8.8-9.3 mg/l, and 9.2-9.8 mg/l, 8.2-8.8 mg/l in the effluent from sampling point-2, 3, 4, 5 and 7 respectively. The value of Temperature were 30.4-31 $^{\circ}$C, 33-36 $^{\circ}$C, 31-34.7°C, 42-46.5°C, 38-38.6°C in the effluent from sampling point-2, 3, 4, 5 and 7 respectively. The concentrations of Total Ammonia (NH_3-N) were 685-697.5 mg/l, 85-120 mg/l, 434-460 mg/l, 997.5-1230 mg/l, 95-147 mg/l in the effluent from sampling point-2, 3, 4, 5 and 7 respectively. The concentrations of Ammonia as Nitrogen (NH_3-N) were 83.09-211.95 mg/l, 8.4-17.03 mg/l,112.77-235.35 mg/l, 464.35-954.67 mg/l, and 7.61-37.85 mg/l in the effluent from sampling point-2, 3, 4, 5 and 7 respectively. The concentrations of Ammonium as Nitrogen (NH_4-N) were 485.55-610.7 mg/l, 76.6-105.44 mg/l, 214.65-325.23 mg/l, 275.33-533.14 mg/l, and 87.39-110.28 mg/l in the effluent from sampling point-2, 3, 4, 5 and 7 respectively. The concentrations of Total Solids (TS) were 112-183 mg/l, 45-90 mg/l, 154-247 mg/l, 215-274 mg/l, and 389-459 mg/l in the effluent from sampling point-2, 3, 4, 5 and 7 respectively. The concentrations of Total Suspended Solids (TSS) were 27-47 mg/l, 13-23 mg/l, 30-84 mg/l, 17-67 mg/l, and 129-179 mg/l in the

effluent from sampling point-2, 3, 4, 5 and 7 respectively. The concentrations of Total Dissoved Solids (TDS) were 85-136 mg/l, 26-69 mg/l, 111-190 mg/l, 176-211 mg/l, and 252-303 mg/l in the effluent from sampling point-2, 3, 4, 5 and 7 respectively.

- From the experimental data it was observed that among all of the wastewater characteristics DO, Total Ammonia, Ammonia, Ammonium exit the standard limit and pH, Temperature, BOD5, COD, TS, TSS, and TDS near or within the standard limit.

- By the analyses of effluent of sampling point-3 and 7, it was shown that the effluent treatment process of Polash and Ghorasal Urea Fertilizer Factories was not satisfactory. It is also noted that the effluent treatment process of Polash Urea Fertilizer Factory was better than Ghorasal Urea Fertilizer Factory.

- By the analyses of effluent of sampling point-2, it was shown that the efficiency of Lagoon was not sufficient and the capacity of the lagoon needs to be increased.

- By the analyses of effluent of sampling point-4 and 5, it was shown that huge amounts of untreated effluent with high concentration of physical and chemical parameters were discharged on the Lakhya River.

- The amount of pollution load discharged from sampling point-4 into the Lakhya River were Biochemical Oxygen Demand (BOD_5) were 2291-2903 kg/day, Chemical Oxygen Demand (COD) were 4124-4286 kg/day, Total Ammonia were 7911-9681 kg/day, Ammonia as Nitrogen (NH_3-N) were 2279.94-5063.22 kg/day, Ammonium as Nitrogen (NH_4-N) were 4617.89-6575.37 kg/day, Total Solids (TS) were 2997-5258 kg/day, Total Suspended Solids (TSS) were 572-1536 kg/day, Total Dissolved Solids (TDS) were 2329-3857 kg/day, The amount of pollution load discharged from sampling point-5 into the Lakhya River were Biochemical Oxygen Demand (BOD_5) were 146-348 kg/day, Chemical Oxygen Demand (COD) were 258-595 kg/day, Total Ammonia (NH_3-N) were 7368-11203 kg/day, Ammonia as Nitrogen (NH_3-N) were 4975.23-6598.68 kg/day, Ammonium as Nitrogen (NH_4-N) were 1903.08-5988.22 kg/day, Total Solids (TS) were 1523-3077 kg/day, Total Suspended Solids (TSS)

were 118-752 kg/day, Total Dissolved Solids (TDS) were 1216-2325 kg/day, The amount of pollution load discharged from sampling point-7 into the Lakhya River were Biochemical Oxygen Demand (BOD_5) were 106-323 kg/day, Chemical Oxygen Demand (COD) were 292-359 kg/day, Total Ammonia (NH_3-N) were 531-896 kg/day, Ammonia as Nitrogen (NH_3-N) were 42.60-230.88 kg/day, Ammonium as Nitrogen (NH_4-N) were 489.27-665.79 kg/day, Total Solids (TS) were 2184-3263 kg/day, Total Suspended Solids (TSS) were 769-1091 kg/day, Total Dissolved Solids (TDS) were 1415-2441 kg/day

- The total amount of pollution load discharged from fertilizer factories into the Lakhya River were Biochemical Oxygen Demand (BOD_5) were 2665-3369 kg/day, Chemical Oxygen Demand (COD) were 4714-5221 kg/day, Total Ammonia (NH_3-N) were 17425-20012 kg/day, Ammonia as Nitrogen (NH_3-N) were 7850.68-10671.21 kg/day, Ammonium as Nitrogen (NH_4-N) were 7164.34-12161.79 kg/day, Total Solids (TS) were 7449-10380 kg/day, Total Suspended Solids (TSS) were 1513-3375 kg/day, Total Dissolved Solids (TDS) were 5467-7004 kg/day

- The level of Biochemical Oxygen Demand (BOD_5) was 8-11 mg/l, 9-11 mg/l, and 11-14mg/l in sampling point-1, 6 and 8 respectively. For the dilution factor the BOD_5 reduced in the sampling point-9 and it was 10-13 mg/l. The level of Chemical Oxygen Demand (COD) was 12-19 mg/l, 15-21 mg/l, and 18-23 mg/l in sampling point-1, 6 and 8 respectively. For the dilution factor the COD reduced in the sampling point-9 and it was 17-22 mg/l. The level of Dissolved Oxygen (DO) was 4-4.8 mg/l, 3.9-4.4 mg/l, 3.78-4.1 mg/l in sampling point-1, 6 and 8 respectively. For the dilution factor pollution load reduced so those DO increased in the sampling point-9 and it was 3.81-4.2 mg/l. The level of pH was 7.5-7.8, 7.9-8.3, 8-8.4 in sampling point-1, 6 and 8 respectively. For the dilution factor pollution load reduced in sampling point-9, so the pH decreased in that point and it was 8.1-8.3. The level of Temperature was 28-31.4 °C, 28-32 °C, 28.2-31.7 °C, and 28.1-30.5 °C in sampling point-1, 6, 8 and 9 respectively. The concentration of Total Ammonia was 0.685-0.71 mg/l in the sampling point-1. In the sampling point-6 it was 0.97-1.19 mg/l. In the sampling point-8 it was 1.09-1.30 mg/l. For the dilution factor the total Ammonia reduced in the sampling point-9 and it was 0.95-1.15 mg/l. The concentration of Ammonia as

Nitrogen (NH_3-N) was 0.01-0.02 mg/l in the sampling point-1. In the sampling point-6 it was 0.08-0.11 mg/l. In the sampling point-8 it was 0.06-0.15 mg/l. For the dilution factor the NH_3-N reduced in the sampling point-9 and it was 0.06-0.11 mg/l. The concentration of Ammonium as Nitrogen (NH_4-N) was 0.67-0.69 mg/l in the sampling point-1. In the sampling point-6 it was 0.93-1.11 mg/l. In the sampling point-8 it was 1.03-1.20 mg/l. For the dilution factor the NH_4-N reduced in the sampling point-9 and it was 0.89-1.06 mg/l. The concentration of Total Solids (TS) was 179-247 mg/l, 193-261 mg/l, and 220-286 mg/l in sampling point-1, 6 and 8 respectively. Total solids were accumulated in the downstream, for this, the value of TS were increased in the sampling point-9 and it were 237-298 mg/l. The concentration of Total Suspended Solids (TSS) was 19-41 mg/l, 20-45 mg/l, 26-58 mg/l in sampling point-1, 6 and 8 respectively. Total suspended solids were accumulated in the downstream, for this, the value of TSS were increased in the sampling point-9 and it were 27-62 mg/l (46±12.55 mg/l). The concentration of Total Dissolved Solids (TDS) was 141-228 mg/l, 162-245 mg/l, and 181-257 mg/l in sampling point-1, 6 and 8 respectively. Total Dissolved solids were accumulated in the downstream, for this, the value of TDS were increased in the sampling point-9 and it were 192-271 mg/l.

- The concentration of most of the water quality parameters in down stream (sampling point-9) is greater than the concentration in up stream (sampling point-1). So it is obviously true that there was a lateral flow between this point either industrial or residential. Different sources are for total Ammonia: u/s 67.08%, fertilizer factories 24.59%, residential area 8.33% ; BOD_5: u/s 79.83%, fertilizer factories 0.39%, residential area 19.78%; COD: u/s 79.49%, fertilizer factories 0.36%, residential area 20.15%; TS: u/s 74.36%, fertilizer factories 0.04%, residential area 25.60%; TSS: u/s 64.36%, fertilizer factories 0.07%, residential area 35.57%; TSS: u/s 76.55%, fertilizer factories 0.04%, residential area 23.41%;

- The level of pollution load along the Lakhya River of Biochemical Oxygen Demand (BOD_5) was 552878-713615 kg/day, 553607-803513 kg/day and 705054-982497 kg/day in the sampling point-1, 6 and 8 respectively. For the dilution factor the BOD_5 load reduced in the sampling point-9 and it was 655124-982923 kg/day. Chemical

Oxygen Demand (COD) was 954971-1188933 kg/day, 1056886-1339188 kg/day and 1158303-1607722 kg/day in the sampling point-1, 6 and 8 respectively. For the dilution factor the COD load reduced in the sampling point-9 and it was 1108672-1519062 kg/l. Total Ammonia was 35686-61103 kg/day in the sampling point-1. In the sampling point-6 it was 59890-86601 kg/day. In the sampling point-8 it was 65469-97357 kg/day. For the dilution factor the total Ammonia reduced in the sampling point-9 and it was 57953-84889 kg/day. Ammonia as Nitrogen (NH_3-N) was 814-1399 kg/day in the sampling point-1. In the sampling point-6 it was 3571-7215 kg/day. In the sampling point-8 it was 5036-9840 kg/day. For the dilution factor the NH_3-N reduced in the sampling point-9 and it was 4535-7217 kg/day. The pollution load of Ammonium as Nitrogen (NH_4-N) was 34681-59765 kg/day in the sampling point-1. In the sampling point-6 it was 55864-83030 kg/day. In the sampling point-8 it was 60433-91997 kg/day. For the dilution factor the NH_4-N reduced in the sampling point-9 and it was 53418-79527 kg/day. Total Solids (TS) was 12414626-15967134 kg/day, 13135585-17230884 kg/day and 14403247-19649938 kg/day in the sampling point-1, 6 and 8 respectively. Total solids were accumulated in the downstream, for this, the load of TS were increased in the sampling point-9 and it were 15017466-21177516 kg/day. Total Suspended Solids (TSS) was 954971-2867428 kg/day, 1006558-3257035 kg/day and 1309386-4398998 kg/day in the sampling point-1, 6 and 8 respectively. Total suspended solids were accumulated in the downstream, for this, the load of TSS were increased in the sampling point-9 and it were 1360643-4645510 kg/day. Total Dissolved Solids (TDS) was 9861153-13558684 kg/day, 12256499-14463229 kg/day and 12942778-16166540 kg/day in the sampling point-1, 6 and 8 respectively. Total suspended solids were accumulated in the downstream, for this, the load of TDS were increased in the sampling point-9 and it were 13656823-17156469 kg/day.

- It was observed that fertilizer factories are the major sources of Total Ammonia load discharged into the Lakhya River in the study area. The amount of total Ammonia load in sampling point-9 is greater than the load of Total Ammonia in sampling point-1. This increment occurred due to the Ammonia load discharged from fertilizer factories. So the Ammonia load discharged from fertilizer factories has a large impact on the Lakhya River water quality. It was also shown that the pollution load of BOD,

COD and TS discharged from sampling point 5, 4 and 7 were negligible as compared to the load discharged from residential area on the right bank of the Lakhya River. So it can be concluded that there was insignificant impact of BOD, COD and TS load discharged from fertilizer factories.

- Highest amount of BOD_5, COD and NH_3-N was found at the discharging point of waste into the river Lakhya and was found decreasing with distance at the down streams. The decay rate was found 0.14/km, 0.12/km and 0.17/km respectively.

- According to the simulated value during the period October'06 to September'07, the concentration varied 0.67-0.75 mg/l, 0-0.04 mg/l, 0.66-0.72 mg/l, 5.19-15.13 mg/l, 6.43-29.71 mg/l, 123.25-315.58 mg/l, 82.35-301.91 mg/l in sampling point-1 and in sampling point-9, it varied 0.87-1.42 mg/l, 0.03-0.15 mg/l, 0.72-1.27 mg/l, 8.29-15.93 mg/l, 12.36-30.38 mg/l, 195.21-375.09 mg/l, and 122.15-369.17 mg/l in case of Total Ammonia, Ammonia, Ammonium, BOD, COD, TS, and TDS respectively for both the points. Maximum concentration occurred in February and minimum in August.

- The percent saturation of Dissolved Oxygen was 54-60 %, 52.5-56 %, 50-53 % in sampling point-1, 6 and 8 respactively. For the dilution factor the pollution load reduced in the sampling point-9, the percent of saturation DO increase in that point and it was 52-54 %.

- Equation generated from the relationship between river flow and concentration of water quality parameters is best suited in the up stream for Total Ammonia, Ammonia, Biochemical Oxygen Demand (BOD), and Chemical Oxygen Demand and in the down stream for Ammonium, Total Solids, and Total Dissolved Solids.

- From the expected load at the downstream the authority could formulate the policy 1) to permit the maximum load of Ammonia discharged from industry 2) The number of industry will permit for sustainable developement in respect of Ammonia

8.2 Recommendations

8.2.1 Introduction

Waste minimization is one of the most important interventions that can help sustain industrial production without compounding onslaughts due to pollution on environmental sinks. One of the chief problems in Bangladesh today concerns its precarious water supply. Water is contaminated by two prime sources: human waste, typical along rivers which attract population settlements upstream and down stream; and industrial and agrochemical wastes, often dumped untreated into lakes and rivers. The latter is noticeable where there is advanced industrial development, as at the Lakhya River located near the Dhaka in Bangladesh.

Ecological balance and environmental protection are among the most critical issues on the agenda of the world community. In many respects, Bangladesh's environmental problem is more severe because of the imbalance between its enormous population and its limited resources. These issues have a tremendous impact at the regional and local levels and demand urgent policy responses from national governments. The water in our oceans, lakes, rivers, and streams supports a wide range of uses. Water can be withdrawn for drinking and other domestic purposes, for industrial processes, or for irrigation. It can support fish populations for commercial exploitation and recreational fishing. To varying degrees, most of these uses depend on the quality of the water. Yet the use of a body of water as a waste receptor can seriously degrade water quality and impair--even preclude--other uses.

All developing countries are confronted with the conflict between development and environment. Economic development requires rapid industrial expansion at minimal cost; but this often leads to detrimental effects on the environment, such as liquid, gaseous, and solid waste pollution. But industrialization without adequate environmen is meaningless. How to reconcile this contradiction is a great challenge to the developing countries especially in Bangladesh.

8.2.2 Recommending Interventions to Minimize Impact

- For the greater interest of the industry as well as for environmental pollution it is necessary to control ammonia contamination of river water up to the allowable limit. For that purpose occasionally released urea plant process condensate instead of direct discharge

into the surface drain should be stored in a lagoon or pond where ammonia will partially evaporate and partially converted to nitric by bacteria. After a certain period water from that lagoon will be discharged to the river by pumping.

- The quality of treatment process must be updated as high value of Ammonia was found on the test result. Untreated effluent discharged from fertilizer factories through the sampling point-5 and 4 must be stopped.

- The pH of waste water should be checked and should be made neutral regarding basic properties before discharge into the river water. For that purposes required those of Alum or sulfuric acid or lime soda may be added at the final pH adjustment basin of the existing system.

- The retaining period of effluent in lagoon was not sufficient as the effluent enters in the lagoon on one side and exit on the other side. So it is necessary to increase retaining period. It is also noted that the capacity of lagoon should be increased as in the rainy season flooding were occurd in the lagoon.

- Leakage from pipeline, valves or ammonia storage tank should be prevented through regular maintenance.

- Public involvement and awareness should be built up about the health hazard that may cause due to industrial activities.

- The ground water quality in and around the factory should be checked periodically in order to ensure no adverse effect on the ground water quality.

- It is known that numerous authorities and laws exist simultaneously in Bangladesh to control industrial pollution. Unfortunately, the authority and jurisdiction of various agencies in this respect is not clearly defined, creating confusion in application of the laws and regulations. There are also a pressing need for summarising the various laws and regulations for (i) smooth and effective implementation/enforcement of the laws/regulations/authority (ii) to establish coordination in terms of taking punitive actions against the polluters and c) to persuade the polluters to comply with the rules and regulations.

- Introduce pollution charges/ permits system. Most environmental experts agree that the best way to tackle pollution is through something called the polluter pays principle. This means that whoever causes pollution should have to pay to clean it up, one way or another

- Ensuring effective environmental assessment of industries

- Industrial wastewater must be treated to the specified standards before discharge into a sewer or watercourse. These standards are set to protect the sewerage infrastructure and workers maintaining the sewerage system, to prevent adverse effects on treatment processes at the downstream sewage treatment works, and to protect aquatic life.

- Waste minimization in industrial processes including avoidance of generation of wastes and productive utilization of generated wastes

- Industrial waste water should be treated by physico-chemical treatment followed by biological treatment. Segregation of process wastewater containing recoverable chemicals from storm water and domestic sewage and treating them separately

8.2.3 Limitations of the Study

- Water quality sample were collected from the mid point between the banks of the river
- Residential effluent discharged from the right bank of the river were not tested in the laboratory
- Effluent discharged from fertilizer factories were measured by float velocity method
- For better test results it was necessary to conduct the tests every months round the year. But due to lack of sufficient time the tests were conducted in the period of June-July'2007
- During the experiment the tests were conducted on samples from limited points of river. If some more points were included the test results would be more perfect and more reliable.

8.2.4 Recommendations for further study

The present study cannot be considered as an ideal one covering all aspects of environmental impacts because this study conducted for the period of June-July, 2007. However, within limitations and scope this study has certainly provided a basis and has focused on various important environmental issues, which should be considered for detailed study in future. Further detailed study in this field is required.

The following recommendations are made for further study in the relevant field:

- A detailed study and investigation may be carried out over the whole year (dry season and wet season) upon the fluctuation of the quality and the quantity of Polash and Ghorasal Urea Fertilizer Factories effluent with time.
- A further study of the water quality of Lakhya River may be performed at different points to identify how extent of the water quality have been affected by the industry
- A study regarding the pollution of air due to Polash and Ghorasal Urea Fertilizer Factories activities may be considered to identify the affected area and the degree of pollution.
- A detail study about ground water quality of the surrounding area of Polash and Ghorasal Urea Fertilizer Factories may have to be under taken to identify the impacts of industrial pollution on ground water.
- A detailed study on how the aquatic habitats were adversely affected by the industry.
- A further study on the effect on plant species and how crop yield has been affected by the industry.

REFERENCES

1. Ahmed, A.U. and Reazuddin, M. (2000), *"Industrial Pollution of Water Systems in Bangladesh"*, University Press Limited, Dhaka, Bangladesh pp 175-178

2. Ahmed, M.F, (1975); *"Clarification of Buriganga river by sedimentation with alam coagulation"*, Journal of the institution of Engineers Bangladesh, vol.3., BUET, Dhaka

3. Alam, R. (2006); *"A study on removal of ammonia from the waste water of Fenchuganj natural gas fertilizer factory"*, M.Sc. Engineering Thesis, Department of Civil engineering, BUET, Dhaka

4. Altman S. J. and Parizek R. R., (1995). *"Dilution of nonpoint source nitrate in ground water"*, J. Environ. Quality, 24, 707-717.

5. American Public Health Association, American Water Works Association, Water pollution control Federation, (APHA, AWWA, WPFC) (1985); *"The standard methods for the examination of water and wastewater"*, 16th Edition.

6. American Society for Testing and Materials (ASTM) *"Annual book of ASTM standard"*, D1293-84, Vol. 11.01 Water-(l) part-I,

7. BKH Consulting Engineers (1994); *"Industrial Pollution Control Management, Interim Report (ADB TA 1769-BAN)"*, Asian Development Bank.

8. Bridgewater A.V, Mumfod C.J, (1979); *"Waste Recycling and Pollution Control Handbook"*, 26 –29.Eniola K.I.T

9. Chapman, D. (1996); *"Water Quality Assessments, A guide to the use of Biota, Sediments and Water in Environmental Engineering"*, Second edition, E&EN SPON.

10. Chindah A. C., Braide A.S. and Sibeudu O. C., (2004); *"Distribution of hydrocarbons and heavy metals in sediment and a crustacean (shrimps-Penaeus notialis) from the bonny/new calabar river estuary"*, Niger Delta. Ajeam-Ragee, 9, 1-14.

11. Department of Environment (DOE) (1991); *"Environmental quality standards for Bangladesh"*, Government of the People's Republic of Bangladesh.

12. Department of Environment (DOE) (1993); *"Water Quality Data of Rivers Buriganga, Meghna, Balu, Shitalakhya, Jamuna (1981-90)"*, Department of Environment, Dhaka, Bangladesh.

13. Emongor V., Kealotswe E., Koorapetse I., Sankwasa S. and Keikanetswe S., (2005). *"Pollution indicators in Gaberone effluent"*, J. Appl. Sci., 5, 147-150.

14. Fakayode S. O, (2005). *"Impact of industrial effluents on water quality of the receiving Alaro River in Ibadan"*, Nigeria, Ajeam-Ragee, 10, 1-13.

15. Government People's Republic of Bangladesh *"Bangladesh Gazette"*, Additional copy, 28 August.

16. IWM (Institute of Water Modelling), August 2004; *"Study to Investigate Alternate Location of the Intake of Saidabad Water Treatment Plant"* Final Report; Dhaka Water Supply and Sewerage Authority (DWASA).

17. Islam, S.A. (2004); *"Estimation of industrial pollution load in Bangladesh"*, M.Sc. Engineering Thesis, Department of Civil engineering, BUET, Dhaka

18. Islam, T., (1977); *"Some characteristics of various waters in and around Dhaka city"*, M.Sc. Engineering Thesis, Department of Civil engineering, BUET, Dhaka

19. Kamal, M.M. (1996); *"Assessment of impact of pollutants in the river Buriganga using a water quality model"*, M.Sc. Engineering Thesis, Department of Civil engineering, BUET, Dhaka

20. Magumdar, T.K. (2005); *"Assessment of water quality of the peripheral river system around Dhaka city"*, M. Engg. Project report, Department of Civil engineering, BUET, Dhaka

21. Olayinka K. O., (2004). *"Studies on industrial pollution in Nigeria: The effect of textile effluents on the quality of groundwater in some parts of Lagos"*, Nigerian Journal of Health and Biomedical Sciences, 3, 44-50.

22. R & D Department, UFFL, (1986); *"A Brief on Environmental Pollution Control Measures in Urea Fertilizer Factory Ltd"*, Ghorassal, Narsingdhi.

23. Saad, M. S. (2000), *"Personal Communication"* Surface Water Modelling Centre (SWMC), Dhaka, Bangladesh.

24. Sarkar, M.S.K.A (2005); *"Study & treatment of surface water for Sylhet city"*, M.Sc. Engineering Thesis, Department of Civil engineering, BUET, Dhaka

25. SIDA (Swedish International Development Cooperation Agency), July 2006; *"Saidabad Raw Water Quality and Pollution Control Study", Final Report;* Dhaka Water Supply and Sewerage Authority (DWASA).

26. Tarikuzzaman Md. *"Impact of the Jamuna fertilizer industry on the surrounding environment"*, M. Engg. Project report, BUET, Dhaka.

27. Ugochukwu C. N. C., (2004), *"Effluent monitoring of oil servicing company and its impact on the environment"*, Ajeam-Ragee, 8, 27-30. 244

28. WARPO (1999) *Topic Paper 4, "National Water Management Plan Project"*, Ministry of Water Resource, Government of Bangladesh.

29. WARPO (2000), Annex G: Environment, *"National Water Management Plan Project"*, Ministry of Water Resource, Government of Bangladesh.

30. WB (World Bank), July 2007; *"Industrial Environmental Compliance and Pollution Control in Greater Dhaka"*, Final Report; Dhaka Water Supply and Sewerage Authority (DWASA).

APPENDIX

APPENDIX

Table A4.1: BOD_5 (mg/l) of effluent from Polash and Ghorasal Urea Fertilizer Factories

Date	Sampling point-2	Sampling point-3	Sampling point-4	Sampling point-5	Sampling point-7
15/06/2007	51	24	148	31	53
22/06/2007	60	29	135	30	19
29/06/2007	50	31	120	21	37
06/07/2007	43	46	143	30	34
13/07/2007	46	41	130	29	41

Table A4.2: COD (mg/l) of effluent from Polash and Ghorasal Urea Fertilizer Factories

Date	Sampling point-2	Sampling point-3	Sampling point-4	Sampling point-5	Sampling point-7
15/06/2007	79	43	234	53	59
22/06/2007	86	47	212	49	64
29/06/2007	78	53	216	37	54
06/07/2007	82	69	211	49	52
13/07/2007	83	64	198	41	59

Table A4.3: DO (mg/l) of effluent from Polash and Ghorasal Urea Fertilizer Factories

Date	Sampling point-2	Sampling point-3	Sampling point-4	Sampling point-5	Sampling point-7
15/06/2007	0.76	2.88	2.90	2.89	2.80
22/06/2007	0.7	2.96	2.91	2.69	3.00
29/06/2007	0.65	2.87	2.83	2.75	2.87
06/07/2007	0.78	2.92	2.81	2.64	2.90
13/07/2007	0.75	2.86	2.84	2.70	2.91

Table A4.4: pH of effluent from Polash and Ghorasal Urea Fertilizer Factories

Date	Sampling point-2	Sampling point-3	Sampling point-4	Sampling point-5	Sampling point-7
15/06/2007	8.5	8.3	8.9	9.2	8.8
22/06/2007	8.4	8.3	8.8	9.7	8.2
29/06/2007	8.9	8.5	9.2	9.5	8.6
06/07/2007	8.4	8.4	9.0	9.8	8.4
13/07/2007	8.4	8.2	9.3	9.7	8.8

Table A4.5: Temperature (°C) of effluent from Polash and Ghorasal Urea Fertilizer Factories

Date	Sampling point-2	Sampling point-3	Sampling point-4	Sampling point-5	Sampling point-7
15/06/2007	30.6	34.0	32.7	42.0	38.0
22/06/2007	31.0	33.0	31.0	46.0	38.0
29/06/2007	31.0	36.0	32.8	45.0	38.4
06/07/2007	30.0	34.0	32.0	46.5	38.0
13/07/2007	30.4	34.6	34.7	46.5	38.6

Table A4.6: NH_3-N (Total Ammonia) (mg/l) of effluent from Polash and Ghorasal Urea Fertilizer Factories

Date	Sampling point-2	Sampling point-3	Sampling point-4	Sampling point-5	Sampling point-7
15/06/2007	690	85	434	997.5	147
22/06/2007	692	93	438	1105	95
29/06/2007	697.5	115	460	1120	131
06/07/2007	685	120	440	1230	125.5
13/07/2007	695	109	450	1040	130

Table A4.7: NH_3-N (mg/l) of effluent from Polash and Ghorasal Urea Fertilizer Factories

Date	Sampling point-2	Sampling point-3	Sampling point-4	Sampling point-5	Sampling point-7
15/06/2007	102.16	8.40	131.88	464.35	37.85
22/06/2007	83.94	9.19	112.77	810.67	7.61
29/06/2007	211.95	17.03	214.14	710.91	23.52
06/07/2007	83.09	14.56	156.04	954.67	15.22
13/07/2007	84.30	8.73	235.35	762.98	33.47

Table A4.8: NH_4-N (mg/l) of effluent from Polash and Ghorasal Urea Fertilizer Factories

Date	Sampling point-2	Sampling point-3	Sampling point-4	Sampling point-5	Sampling point-7
15/06/2007	587.84	76.60	302.12	533.14	109.15
22/06/2007	608.06	83.81	325.23	294.33	87.39
29/06/2007	485.55	97.97	245.86	409.09	107.48
06/07/2007	601.91	105.44	283.96	275.33	110.28
13/07/2007	610.70	100.27	214.65	277.02	96.53

Table A4.9: Total Solids (mg/l) of effluent from Polash and Ghorasal Urea Fertilizer Factories

Date	Sampling point-2	Sampling point-3	Sampling point-4	Sampling point-5	Sampling point-7
15/06/2007	183	90	247	274	459
22/06/2007	145	75	235	245	428
29/06/2007	128	67	157	228	532
06/07/2007	170	45	259	221	389
13/07/2007	112	69	154	215	432

Table A4.10: Total Suspended Solids (mg/l) of effluent from Polash and Ghorasal Urea Fertilizer Factories

Date	Sampling point-2	Sampling point-3	Sampling point-4	Sampling point-5	Sampling point-7
15/06/2007	47	21	84	67	179
22/06/2007	39	15	76	38	156
29/06/2007	34	23	30	17	134
06/07/2007	43	19	69	45	137
13/07/2007	27	13	43	39	129

Table A4.11: Total Dissolved Solids (mg/l) of effluent from Polash and Ghorasal Urea Fertilizer Factories

Date	Sampling point-2	Sampling point-3	Sampling point-4	Sampling point-5	Sampling point-7
15/06/2007	136	69	163	207	280
22/06/2007	106	60	159	207	272
29/06/2007	94	44	122	211	398
06/07/2007	127	26	190	176	252
13/07/2007	85	56	111	176	303

Table A5.1: Flow rate (m^3/S) of effluent from Polash and Ghorasal Urea Fertilizer Factories

Date	Sampling point-2	Sampling point-3	Sampling point-4	Sampling point-5	Sampling point-7
15/06/2007	0.125	0.0263	0.211	0.130	0.0706
22/06/2007	0.140	0.0265	0.234	0.086	0.0648
29/06/2007	0.130	0.0262	0.221	0.081	0.071
06/07/2007	0.140	0.0266	0.235	0.080	0.065
13/07/2007	0.150	0.0266	0.249	0.082	0.070

Table A5.2: Pollution load in kg/day (Industrial and Residential) discharged from sampling point-4

Date	BOD_5	COD	Total Ammonia	NH_3-N	NH_4-N	TS	TSS	TDS
15/06/2007	2698	4266	7912	2404.24	5507.76	4503	1531	2972
22/06/2007	2729	4286	8855	2279.63	6575.37	4751	1536	3215
29/06/2007	2291	4124	8783	4088.45	4694.55	2998	573	2330
06/07/2007	2903	4284	8934	3168.48	5765.52	5259	1401	3857
13/07/2007	2797	4260	9681	5063.11	4617.89	3313	925	2388

Table A5.3: Pollution load in kg/day (Residential) discharged from sampling point-4

Date	BOD_5	COD	Total Ammonia	TS	TSS	TDS
15/06/2007	2092.76	3315.00	266.85	2322.00	976.03	1345.97
22/06/2007	1937.22	3138.26	271.94	2825.50	1030.45	1795.05
29/06/2007	1659.55	3128.32	688.78	1408.46	138.88	1174.11
06/07/2007	2277.62	3133.69	372.21	3099.00	837.18	2261.81
13/07/2007	2106.38	3036.93	423.41	1703.00	545.29	1157.71

Table A5.4: Pollution load in kg/day discharged from sampling point-5

Date	BOD_5	COD	Total Ammonia	NH_3-N	NH_4-N	TS	TSS	TDS
15/06/2007	348	595	11204	5215.78	5988.22	3078	753	2325
22/06/2007	223	364	8211	6024.01	2186.99	1820	282	1538
29/06/2007	147	259	7838	4975.02	2862.98	1596	118	1476
06/07/2007	207	339	8502	6598.92	1903.08	1528	311	1217
13/07/2007	205	290	7368	5405.37	1962.63	1523	276	1247

Table A5.5: Pollution load in kg/day discharged from sampling point-7

Date	BOD_5	COD	NH_3-N	NH_4-N	TS	TSS	TDS
15/06/2007	323	360	897	665.79	2800	1092	1708
22/06/2007	106	358	532	489.27	2396	873	1522
29/06/2007	227	331	804	659.32	3264	822	2441
06/07/2007	191	292	705	619.33	2185	769	1415
13/07/2007	248	357	786	583.81	2613	780	1833

Table A5.6: Total Pollution load in kg/day discharged from Polash and Ghorasal Fertilizer Factories

Date	BOD_5	COD	Total Ammonia	NH_3-N	NH_4-N	TS	TSS	TDS
15/06/2007	3370	5221	20013	7851.21	12161.79	10380	3376	7005
22/06/2007	3059	5009	17598	8346.37	9251.63	8968	2692	6276
29/06/2007	2665	4715	17425	9208.15	8216.85	7857	1514	6248
06/07/2007	3302	4915	18140	9852.06	8287.94	8971	2481	6490
13/07/2007	3250	4907	17835	10670.7	7164.34	7449	1981	5467

Table A6.1: Flow rate (m^3/S) in different points along the Lakhya River

Date	**Sampling point-1**	**Sampling point-6**	**Sampling point-8**	**Sampling point-9**
15/06/2007	759.106	759.201	759.261	759.331
22/06/2007	941.576	942.429	942.858	943.289
29/06/2007	1032.429	1033.324	1033.772	1034.220
06/07/2007	809.459	810.615	811.185	811.750
13/07/2007	581.732	582.499	582.882	583.266

Table A6.2: The levels of BOD_5 (mg/l) at different points along the Lakhya River

Date	**Sampling point-1**	**Sampling point-6**	**Sampling point-8**	**Sampling point-9**
15/06/2007	10	11	13	12
22/06/2007	8	9	12	10
29/06/2007	8	9	11	11
06/07/2007	9	10	12	11
13/07/2007	11	11	14	13

Table A6.3: The levels of COD (mg/l) at different points along the Lakhya River

Date	**Sampling point-1**	**Sampling point-6**	**Sampling point-8**	**Sampling point-9**
15/06/2007	18	20	23	22
22/06/2007	13	15	18	17
29/06/2007	12	15	18	17
06/07/2007	17	19	21	20
13/07/2007	19	21	23	22

Table A6.4: The levels of DO (mg/l) at different points along the Lakhya River

Date	**Sampling point-1**	**Sampling point-6**	**Sampling point-8**	**Sampling point-9**
15/06/2007	4.80	4.40	4.10	4.20
22/06/2007	4.56	4.20	4.00	4.00
29/06/2007	4.52	4.00	3.84	3.90
06/07/2007	4.50	3.90	3.78	3.83
13/07/2007	4.00	3.90	3.80	3.81

Table A6.5: The levels of pH at different points along the Lakhya River

Date	Sampling point-1	Sampling point-6	Sampling point-8	Sampling point-9
15/06/2007	7.7	8.3	8.4	8.3
22/06/2007	7.6	8.1	8.2	8.1
29/06/2007	7.5	7.9	8	8.1
06/07/2007	7.8	8.1	8.1	8.1
13/07/2007	7.7	8.1	8.2	8.2

Table A6.6: The levels of Temperature (^{o}C) at different points along the Lakhya River

Date	Sampling point-1	Sampling point-6	Sampling point-8	Sampling point-9
15/06/2007	28	28	28.2	28.1
22/06/2007	29	29.7	29.2	29
29/06/2007	30	30.7	30.6	30
06/07/2007	30	32	31	30.5
13/07/2007	31.4	31.6	31.7	31

Table A6.7: The levels of NH_3-N (Total Ammonia) at different points along Lakhya River

Date	Sampling point-1	Sampling point-6	Sampling point-8	Sampling point-9
15/06/2007	0.708	1.15	1.25	1.10
22/06/2007	0.69	1.03	1.16	1.00
29/06/2007	0.685	0.97	1.09	0.95
06/07/2007	0.70	1.09	1.20	1.05
13/07/2007	0.71	1.19	1.30	1.15

Table A6.8: The levels of NH_3-N (mg/l) at different points along the Lakhya River

Date	Sampling point-1	Sampling point-6	Sampling point-8	Sampling point-9
15/06/2007	0.02	0.11	0.15	0.11
22/06/2007	0.01	0.07	0.09	0.06
29/06/2007	0.01	0.04	0.06	0.06
06/07/2007	0.02	0.07	0.08	0.07
13/07/2007	0.02	0.08	0.10	0.09

Table A6.9: The levels of NH_4-N (mg/l) at different points along the Lakhya River

Date	Sampling point-1	Sampling point-6	Sampling point-8	Sampling point-9
15/06/2007	0.69	1.04	1.10	0.99
22/06/2007	0.68	0.96	1.07	0.94
29/06/2007	0.67	0.93	1.03	0.89
06/07/2007	0.68	1.02	1.12	0.98
13/07/2007	0.69	1.11	1.20	1.06

Table A6.10: The levels of Total Solids (mg/l) at different points along the Lakhya River

Date	Sampling point-1	Sampling point-6	Sampling point-8	Sampling point-9
15/06/2007	205	223	257	267
22/06/2007	190	207	241	251
29/06/2007	179	193	220	237
06/07/2007	182	216	255	285
13/07/2007	247	261	286	298

Table A6.11: The levels of Total Suspended Solids at different points along Lakhya River

Date	Sampling point-1	Sampling point-6	Sampling point-8	Sampling point-9
15/06/2007	29	30	38	39
22/06/2007	34	40	54	57
29/06/2007	27	31	40	45
06/07/2007	41	45	58	62
13/07/2007	19	20	26	27

Table A6.12: The levels of Total Dissolved Solids at different points along Lakhya River

Date	Sampling point-1	Sampling point-6	Sampling point-8	Sampling point-9
15/06/2007	176	203	218	228
22/06/2007	156	166	187	194
29/06/2007	152	162	181	192
06/07/2007	141	175	194	223
13/07/2007	228	245	257	271

Table A6.13: BOD_5 load in kg/day at different points along the Lakhya River

Date	Sampling point-1	Sampling point-6	Sampling point-8	Sampling point-9
15/06/2007	655867	721545	852802	787274
22/06/2007	650817	732833	977555	815002
29/06/2007	713615	803513	982497	982923
06/07/2007	629435	700371	841037	771487
13/07/2007	552878	553607	705054	655124

Table A6.14: COD load in kg/day at different points along the Lakhya River

Date	Sampling point-1	Sampling point-6	Sampling point-8	Sampling point-9
15/06/2007	1180562	1311899	1508803	1443336
22/06/2007	1057578	1221388	1466333	1385503
29/06/2007	1070422	1339188	1607722	1519062
06/07/2007	1188933	1330706	1471814	1402704
13/07/2007	954971	1056886	1158303	1108672

Table A6.15: Total Ammonia load in kg/day at different points along the Lakhya River

Date	Sampling point-1	Sampling point-6	Sampling point-8	Sampling point-9
15/06/2007	46435	75434	82000	72167
22/06/2007	56133	83869	94497	81500
29/06/2007	61103	86601	97357	84889
06/07/2007	48956	76340	84104	73642
13/07/2007	35686	59890	65469	57953

Table A6.16: NH_3-N (kg/day) load at different points along the Lakhya River

Date	Sampling point-1	Sampling point-6	Sampling point-8	Sampling point-9
15/06/2007	1312	7215	9840	7217
22/06/2007	814	5700	7332	4890
29/06/2007	892	3571	5359	5361
06/07/2007	1399	4903	5607	4909
13/07/2007	1005	4026	5036	4535

Table A6.17: NH_4-N (kg/day) load at different points along the Lakhya River

Date	Sampling point-1	Sampling point-6	Sampling point-8	Sampling point-9
15/06/2007	45255	68219	72160	64950
22/06/2007	55319	78169	87165	76610
29/06/2007	59765	83030	91997	79527
06/07/2007	47557	71438	78497	68732
13/07/2007	34681	55864	60433	53418

Table A6.18: Total Solids load in kg/day at different points along the Lakhya River

Date	Sampling point-1	Sampling point-6	Sampling point-8	Sampling point-9
15/06/2007	13445285	14627678	16859239	17516855
22/06/2007	15456912	16855154	19632566	20456543
29/06/2007	15967134	17230884	19649938	21177516
06/07/2007	12728581	15128021	17872028	19988532
13/07/2007	12414626	13135585	14403247	15017466

Table A6.19: Total Suspended Solids load in kg/day at different points along the Lakhya River

Date	Sampling point-1	Sampling point-6	Sampling point-8	Sampling point-9
15/06/2007	1902016	1967849	2492806	2558642
22/06/2007	2765974	3257035	4398998	4645510
29/06/2007	2408450	2767655	352716	4021047
06/07/2007	2867428	3151671	4065010	4348382
13/07/2007	954971	1006558	1309386	1360643

Table A6.20: Total Dissolved Solids load in kg/day at different points along the Lakhya River

Date	Sampling point-1	Sampling point-6	Sampling point-8	Sampling point-9
15/06/2007	11543269	13315778	14300833	14958213
22/06/2007	12690938	13516694	15233568	15811033
29/06/2007	13558684	14463229	16166540	17156469
06/07/2007	9861153	12256499	13596758	15640150
13/07/2007	11459655	12330339	12942778	13656823

Table A7.1: Lakhya River flow (m^3/s) and water quality parameters in mg/l at sampling point-1

Month	River flow	Total NH_3-N	NH_3-N	NH_4-N	BOD_5	COD	TS	TDS
Oct-06	525.38	0.72	0.02	0.70	11.37	20.91	242.88	218.93
Nov-06	77.26	0.74	0.04	0.71	14.64	28.57	306.20	291.21
Dec-06	32.37	0.75	0.04	0.72	14.97	29.34	312.55	298.45
Jan-07	14.15	0.75	0.04	0.72	15.10	29.65	315.12	301.39
Feb-07	10.90	0.75	0.04	0.72	15.13	29.71	315.58	301.91
Mar-07	11.22	0.75	0.04	0.72	15.12	29.70	315.53	301.86
Apr-07	43.76	0.75	0.04	0.72	14.89	29.14	310.94	296.61
May-07	56.61	0.74	0.04	0.72	14.79	28.92	309.12	294.54
Jun-07	610.60	0.71	0.02	0.69	10.75	19.45	230.84	205.18
Jul-07	790.98	0.70	0.01	0.69	9.43	16.37	205.35	176.08
Aug-07	1372.08	0.67	0.00	0.66	5.19	6.43	123.25	82.35
Sep-07	1227.75	0.67	0.00	0.67	6.24	8.90	143.64	105.63

Table A7.2: Lakhya River flow (m^3/s) and water quality parameters in mg/l at sampling point-9

Month	River flow	Total NH_3-N	NH_3-N	NH_4-N	BOD_5	COD	TS	TDS
Oct-06	527.26	1.21	0.10	1.06	13.04	23.56	307.03	275.71
Nov-06	77.49	1.39	0.14	1.24	15.56	29.50	366.31	357.11
Dec-06	32.37	1.41	0.15	1.26	15.81	30.09	372.25	365.28
Jan-07	14.13	1.42	0.15	1.26	15.91	30.33	374.66	368.58
Feb-07	10.88	1.42	0.15	1.27	15.93	30.38	375.09	369.17
Mar-07	11.18	1.42	0.15	1.27	15.93	30.37	375.05	369.12
Apr-07	43.81	1.40	0.15	1.25	15.74	29.94	370.75	363.21
May-07	56.65	1.40	0.15	1.25	15.67	29.77	369.05	360.89
Jun-07	611.29	1.18	0.10	1.03	12.57	24.45	295.95	260.50
Jul-07	792.74	1.10	0.08	0.95	11.55	20.05	272.04	227.65
Aug-07	1375.63	0.87	0.03	0.72	8.29	12.36	195.21	122.15
Sep-07	1229.65	0.93	0.04	0.78	9.10	14.29	214.45	148.57

Table A7.3: Concentration of water quality parameters in mg/l at 500m apart from sampling Point-9

Date	Total Ammonia	BOD_5	COD
06/07/2007	1.03	10.5	18.5

Table A7.4: Percent saturation of Dissolved Oxygen (DO) along the Lakhya River

Date	Sampling point-1	Sampling point-6	Sampling point-8	Sampling point-9
15/06/2007	60	56	52	54
22/06/2007	59	55	53	53.5
29/06/2007	58	54	52	52.5
06/07/2007	58	54	50	52
13/07/2007	54	52.5	52	52.5

বাংলাদেশ প্রকৌশল বিশ্ববিদ্যালয়
নং 105955
তাং 25/10/08
লাইব্রেরী, ঢাকা